AGRONOMIC MANAGEMENT OF AGED SEEDLINGS OF IMPROVED WHITE PONNI RICE VARIETY FOR KARAIKAL REGION

Thesis submitted in part fulfilment of the requirements for the award of the **Degree of Master of Science** (Agriculture) in **Agronomy** to the Tamil Nadu Agricultural University, Coimbatore.

By

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CERTIFICATE

This is to certify that the thesis entitled **"AGRONOMIC MANAGEMENT OF AGED SEEDLINGS OF IMPROVED WHITE PONNI RICE VARIETY FOR KARAIKAL REGION"** submitted in part fulfilment of the requirements for the award of the degree of **Master of Science** (Agriculture) in **AGRONOMY** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. J. SENTHIL KUMAR** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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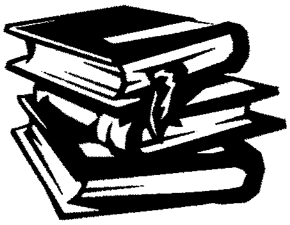
Date: 27. 12. 2002 **EXTERNAL EXAMINER**



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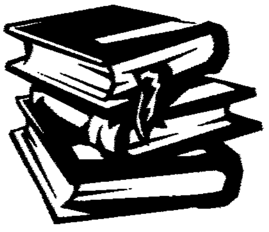

ABSTRACT

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AGRONOMIC MANAGEMENT OF AGED SEEDLINGS OF IMPROVED WHITE PONNI RICE VARIETY FOR KARAIKAL REGION

by

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Two field experiments were conducted during *Rabi* season 2001 –2002 (one in late *Samba* and another in late *Thaladi* season) at the Eastern Block of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, which is 8 Km from the sea coast of Bay of Bengal, at an altitude of 4 m MSL (Latitude between 10°49' and 11°01' N; Longitude between 78°43' and 79° 52'). The treatment combinations consisted of four ages of seedlings (25, 32, 39 and 46 days old) and two plant population (50 and 60 hills m^{-2} with a spacing of 20m x 10 and 15x10 cm, respectively) in the mainplots and two levels of nitrogen (100 per cent recommended dose *viz.,* 150 kg N ha^{-1} and 75 per cent recommended dose *viz.,* 112.5 kg N ha^{-1}) in the subplots replicated thrice. A common recommended dose of 50 kg ha^{-1} each of P_2O_5 and K_2O were applied to all the treatments. Both the experiments were conducted in the same field (Field No. A_8). The first crop was raised from 13.09.2001 to 07.02.2002 and the second crop was raised from 23.10.2001 to 18.03.2002. The soil type of the experimental field was sandy clay loam (*Fluventic Ustropept*) with low status of available nitrogen (151 kg ha^{-1}) and

medium status of both available phosphorus (16 kg ha^{-1}) and available potassium (158 kg ha^{-1}). The soil was having an EC of 0.29 dSm^{-1} and the pH of 7.20.

The pooled analysis of the results of the two field experiments revealed that the grain yield as well as the straw yield was not influenced significantly by planting the seedlings at different ages at both the levels of plant population and nitrogen. Planting of 25,32,39 and 46 days old seedlings gave 3341, 3122, 3148 and 3033 kg ha^{-1} grain yield, respectively during late *Samba* season. Similarly, planting of 23,32,39 and 46 days old seedlings registered 5136, 5264, 4880 and 5048 kg ha^{-1} grain yield, respectively during late *Thaladi* season. The overall average yield level due to various treatments was higher during late *Thaladi* season (5082 kg ha^{-1}) than at late *Samba* season (3161 kg ha^{-1}) due to significant favourable effect of climate during late *Thaladi* season. The favourable effect of climate during late *Thaladi* season resulted in an increase in panicle length, panicle weight and the number of filled grains $panicle^{-1}$ which ultimately resulted in the overall high average yield. Recommended plant population of 50 hills m^{-2} produced 3304 and 5152 kg ha^{-1} during late *Samba* and late *Thaladi* season, respectively. Whereas, planting at higher plant population of 133 per cent (33% extra seedlings) with 66 hills m^{-2} gave 3018 and 5012 kg ha^{-1} during late *Samba* and late *Thaladi* seasons, irrespective of age of seedlings and nitrogen levels. Application of 100 per cent recommended dose of nitrogen (150 kg ha^{-1}) produced 3114 and 5048 kg ha^{-1} during late *Samba* and late *Thaladi* season, respectively. The grain yield was 3207 and 5116 kg ha^{-1} during late *Samba* and late *Thaladi* season, respectively due to application of 75 per cent recommended dose of nitrogen. The overall straw yield due to various treatments was 6028 kg ha^{-1} during late *Thaladi* season and it was 4562 kg ha^{-1} during late *Samba* season.

The overall economics of the study revealed that planting of 25 days old seedlings at 50 hills m^{-2} with 100 per cent recommended dose of nitrogen gave the highest gross return (Rs.27049), net return (Rs.8899) and benefit cost ratio (1.49) during late *Samba* season. Similarly planting of 25 days old seedlings at 50 hills m^{-2} with 75 per cent recommended dose of nitrogen gave the highest gross return (Rs.41517), net return (Rs.21410) and benefit cost ratio (2.06) during late *Thaladi* season. When planting was done with 32, 39 and 46 days old seedlings, the yield reductions were 219, 193 and 308 kg ha^{-1}, respectively as compared to 25 days old seedlings during late *Samba* season. Because of this, there was reduction in net return to the tune of Rs.1267, Rs.1034 and Rs.1919, respectively due to planting of 32,39 and 46 days old seedlings. During late *Thaladi* season, planting of 32 days old seedlings was found to give 120 kg ha^{-1} extra grain yield per ha as compared to 25 days old seedlings and hence there was an increased net return of Rs.522 ha^{-1}. However, when planting was done with 39 and 46 days old seedling the yield was reduced by 256 and 88 kg ha^{-1}, respectively and hence, there was a reduction in net return to the tune of Rs.1959 and Rs.721 ha^{-1}, respectively.

It is recommended that planting of Improved *White Ponni* during late *Samba* season (1st to 31st October) with 25 days old seedlings at 50 hills m^{-2} with 100 per cent recommended nitrogen is economical. Planting with 32 to 46 days old seedlings results in yield loss of 193 to 308 kg ha^{-1} during late *Samba* season. Similarly, planting of 25 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen is economical during late *Thaladi* season (1st November to1st week of December). During late *Thaladi* season, planting can be taken up even with 46 days old seedlings as the reduction in grain yield was very minimum (88 kg ha^{-1}).

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS

%	-	per cent
cc	-	cubic centimeter
CD	-	Critical difference
cm	-	centimeter
DMP	-	Dry Matter Production
DAT	-	Days After Transplanting
dSm^{-1}	-	Desi Siemen per meter
EC	-	Electrical conductivity
Fig.	-	Figure
g	-	gram
grains $panicle^{-1}$	-	grains per panicle
ha	-	hectare
hills m^{-2}	-	hills per meter square
LAI	-	Leaf Area Index
I.W. Ponni	-	*Improved White Ponni*
m	-	meter
mm	-	millimeter
MT	-	Maximum tillering
STCR	-	Soil Test Crop Response
A	-	Age of seedlings
P	-	Plant population
N	-	Nitrogen
P	-	Phosphorus
K	-	Potassium
PI	-	Panicle initiation
SE d	-	Standard error of mean deviation
t ha^{-1}	-	tonnes per hectare
Viz.	-	namely

INTRODUCTION

CHAPTER 1

INTRODUCTION

Rice is the most important and staple food for more than half of the global population. Rice provides more calories per hectare than any other cereal crop (Thirupathi *et al.*, 2000). Although rice is cultivated in more than 90 countries spread over six continents, more than 92 per cent of the rice is produced and consumed in Asian countries (Subramanian, 1998). The demand for rice is expected to grow faster than production in most of the countries (Swaminathan, 1998). Recent studies have revealed that Asia accounts for about 90 per cent of world's rice area and 92 per cent of world's rice production (Hazra, 2001).

Among rice growing countries, India has the largest area under rice in the world (44 m.ha) and ranks second in production, next to China. These two countries account for over 55 per cent of total rice production from about 50 per cent of world's area under rice. India's share in the world's production is 22.1 per cent. In India, rice is grown in many situations out of compulsions dictated by varying climatic, soil and water regimes such as water logging, deep water, flood, high rainfall, salinity, alkalinity, acidity, high temperature, high humidity etc. The rice crop has wide physical adaptability and it is grown below sea level up to an elevation of 2000 meters (Hazra, 2001).

The area under rice, which was about 31 m.ha during 1950-51, has increased to 42 m.ha during 1989-90 and thereafter it is stagnating. Rice crop occupies about 23 per cent of the gross cropped area and accounts for 35 per cent of area under food grains and 43 per cent of area under cereals. The rice production has registered an appreciable increase from 20.6 million tonnes in 1950-51 to 86.0 million tonnes during 1998-99. The total rice production in the country constitutes about 45 per cent of the total production of cereals and 41 per cent of that of food grains. The four-fold increase in production has been mainly because of improvement in the productivity levels. The productivity of rice, which was 668 kg ha^{-1} in 1950-51 reached to a level of 1928 kg ha^{-1} during 1998-99. The productivity level of rice varies widely between different states ranging from 1t ha^{-1} to more than 3 t ha^{-1} (Hazra, 2001).

At the present level of population growth, India would be required to add annually not less than 2.5 million tonnes of rice to sustain the present level of self sufficiency (Pillai, 1996). The rice requirement by 2020 would be around 140 million tonnes (Hazra, 2001).

Rice is also the staple food crop of Tamil Nadu and Union Territory of Pondicherry. In Tamil Nadu, rice is cultivated to an extent of about 22 lakh hectares, accounting for about one third of the gross cropped area of the state. The total production of rice is about 75 lakh tonnes, constituting about 85 per cent of the total food grain output of the state. Tamil Nadu ranks second among the states in rice yield level. The area under rice, which was about 26 lakh hectares during seventies, has come down to about 22 lakh hectares during nineties (Suu and Kombairaju, 2001).

Cauvery Delta zone is the potential area of traditional rice cultivation in Tamil Nadu. This zone accounts for about 22.3 per cent of the rice area and 25.3 per cent of rice production of the state. Hence, it is named as "The Rice Bowl of Tamil Nadu". In this zone, rice is cultivated in three distinct seasons *viz*., *Kuruvai* followed by *Thaladi* (in double crop wetlands) and *Samba* (in single crop wetlands). *Kuruvai* (*Kharif*) rice solely depends on the *Cauvery* river water from Mettur dam, whereas *Samba* and *Thaladi* (*Rabi*) rice utilizes heavy monsoon rains at the beginning of the season besides supplemental irrigation by canal water at later stages. Hence, time of release of Mettur dam water for irrigation decides the *Kuruvai, Samba* and *Thaladi* rice production. When the water is released late beyond the scheduled date of 12th June, the harvest of *Kuruvai* and planting of *Samba/Thaladi* crops overlaps, leading to labour shortage in this zone (Ponnusamy *et al*., 2000).

In the Union Territory of Pondicherry, rice is grown over an area of 25,444 hectares with a production of 59,434 tonnes (GOP, 2001). The Union Territory of Pondicherry has four administrative regions *viz*., Pondicherry, Karaikal (both in Tamil Nadu), Yanam (in Andhra Pradesh) and Mahe (in Kerala). Karaikal is 135 km away from Pondicherry in the south, Mahe is about 350 km away on the west and Yanam is 800 km away from Pondicherry in the north. All the four regions of Union Territory of Pondicherry are on the sea coast. Mahe is on the west coast (Arabian sea) and the other three are in the east coast (Bay of Bengal). In Karaikal region, rice is grown in an area of 10751 hectares and is cultivated in three distinct seasons *viz., Kuruvai* (June-September), *Samba* (August -February) and *Thaladi* (October-February). Karaikal region was once known as "The Rice Bowl of Pondicherry" as majority of total rice production of the Union Territory of Pondicherry was from Karaikal. During seventies the area under rice was 13,420 hectares in Karaikal region (GOP, 1981) and it has now been reduced to 10,751 hectares during 2000-01. Of this, the area under *Kuruvai* was 2972 hectares, which has been reduced to just 1561 hectares during 2000-01. This reduction in area under *Kuruvai* has resulted in an increase in rice area under *Samba* to 7559 hectares during 2000-01 from the previous area of 7179 hectares during the seventies. This is mainly due to non-availability of *Cauvery* water for *Kuruvai* rice.

Late receipt of *Cauvery* water in the canals forced the farmers of Karaikal region to convert half of the area under *Kuruvai* into *Samba* area. Those farmers who have underground water supply from filter points or bore wells are taking up *Kuruvai* nurseries and then transplanting expecting canal water during the fag end of its growth. Those who have no filter points or bore wells abandon *Kuruvai* crop and make up their mind at least to raise *Samba* crop in time. But timely planting of *Samba* crop is also getting affected in recent years due to late receipt of *Cauvery* water in canals. Farmers are often forced to transplant aged seedlings in *Samba* season due to late receipt of water. Further delay of canal water affects *Thaladi* rice crop also due to severe shortage of labourers in view of overlapping of planting of *Samba* and *Thaladi* crops and harvesting of *Kuruvai* crops, resulting in planting of aged seedlings in *Thaladi* season. Thus the farmers in Karaikal region are frequently forced to take up transplanting of aged seedlings in late *Samba* or late *Thaladi* seasons.

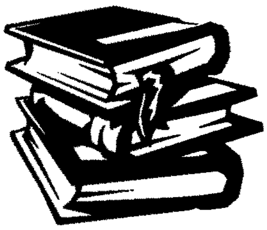
The most popular rice cultivar in this region during *Samba* and *Thaladi* seasons is "Improved *White Ponni*" which is a fine grain variety fetching a good market price after the harvest season and during the off-season. The variety *I.W.Ponni* normally lodges at higher levels of nitrogen and results in yield loss. Inspite of these constraints in *I.W.Ponni*, the farmers prefer this variety during *Samba* and *Thaladi* seasons due to its marketability. Planting of aged seedlings generally reduces the yield (Ramasamy, 1996).

Hence, the present investigation was taken up to find out the suitable agronomic management techniques of aged seedlings of *I.W.Ponni* rice variety for Karaikal region. The experiment was taken up with seedlings of different ages under two levels of plant population and two levels of nitrogen with the following objectives.

i. To find out the effect of aged seedlings, plant population and nitrogen levels on the yield attributes and yield of *I.W.Ponni* rice variety.

ii. To investigate the effect of age of seedlings, plant population and nitrogen levels on the uptake of N, P and K of *I.W.Ponni* rice variety and available N, P and K status of the soil.

iii. To workout the economics of planting of aged seedlings of *I.W.Ponni* under different plant population and nitrogen levels.



REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

Rice is the predominant crop in any lowland ecosystem. Its cultivation is regularized by the availability of water in the rivers and canals. Usually farmers raise seedlings in the nursery and transplant in the main field. But due to late receipt of water in the canals, often caused by the vagaries of monsoon rains in the catchment areas, the transplanting is delayed. At this juncture, the farmers have left with no other alternatives but for transplanting their fields with the available aged seedlings (Ramasamy and Babu, 1997). The literatures related to the management of the aged seedlings are reviewed in this chapter.

2.1. Age of seedlings

Late planting of rice has become a common practice because of late receipt of water, natural calamities, resource constraints and/or prevailing cropping system. In many farming situations, planting time and the age of seedlings are highly variable due to the economic, agronomic and management constraints faced by the farmers (Krishnan and Nayak, 1997).

Traditional photosensitive varieties with aged seedlings were grown under such situations. Certain high yielding varieties were found promising at different places for delayed planting (Mishra, 1985 and Panda *et al.*, 1981). There is, however, varied opinion on the optimum age of seedlings for getting maximum yield under such situation (Rao and Murthy, 1982 and Patel *et al.*, 1983). Farmers often use 35 to 50 days old seedlings in place of 25 days old seedlings, which is the recommended age (Pattar *et al.*, 2001).

For late transplanted seedlings, improvement in yields may be manipulated by modified agronomic management practices like application of enhanced dose of nitrogen and planting of one to two seedlings extra per hill (Setty *et al.*, 1987). Several workers have identified that old (aged) seedling were found to give higher yields than young seedlings under certain situations (Ramasamy and Babu, 1997).

2.1.1. Plant height

In an experiment conducted on a medium black soil during *Kharif* (wet) seasons of 1977, 1978 and 1979 at Jabalpur with a short duration rice cultivar *JR 25-423-2-L* under 120 kg N ha^{-1}, it was found that plant height was maximum when young seedlings of 20 days old were used for transplanting (20x15 cm spacing with 33 hills m^{-2}) as compared to 28 and 36 days old seedlings (Koshta *et al.*, 1987).

However, for a similar short duration variety (*Rasi*-115 days) when 30,45 and 60 days old seedlings were planted (20x10 cm with 50 hills m^{-2}) under different levels of fertilizer nitrogen (0,40,80,120 and 160 kg ha^{-1}) in a clay loam soil during *Rabi* (dry) season at DRR farm, Hyderabad, it was observed that 30 to 45 days old seedlings were taller than 60 days old seedlings as observed at the time of maturity. The reason was that 60 days old seedlings remained in the nursery for longer period till it attained maximum tillering stage and transplanting at this stage did not provide sufficient nutrients to vegetative growth, which led to reduction in plant height (Singh *et al.*, 1996 and 1999). It may be inferred from these literatures that for the rice varieties of almost similar duration (short duration) the age of seedlings varies with soil type, season and climate (geographic location), irrespective of plant population and nitrogen levels.

2.1.2. Tillering

In an experiment conducted at Jabalpur during *Kharif* season, in a short duration rice cultivar *JR 25-423-2-L*, with 20,28 and 36 days old seedlings in medium black soil, it was observed that the number of tillers per plant was found to decrease with increase in age of seedlings at 120 kg N ha^{-1} (Koshta *et al.*, 1987). At Bhubaneswar, in a short duration rice variety *Parijat*, it was observed that planting two-week-old seedlings had maximum number of tillers followed by three, four and five week old seedlings as observed on 50 days after sowing (Das *et al.*, 1988).

Studies at Bangladesh in two short duration rice varieties (*BR 14* and *IR 50*) with 20,40,60 and 80 days old seedlings also revealed that the tiller number was found to decrease with increasing age of seedlings. The tiller number production was lower in 80 days old seedlings as compared to seedlings of other ages. After transplanting, older seedlings required lesser time to reach the booting stage than younger ones. The percentage of tillers reaching the booting stage was the highest for primary tillers and the lowest for tertiary tillers (Roy and Sattar, 1991).

Studies at Bhubaneshwar with four rice varieties of varying crop duration *viz.*, very short duration rice variety *Parijat* (95 days), short duration rice varieties such as *Sarasa*, *IR 36*, *Ratna* (120 days), medium duration rice variety *Jajati* (135 days) and long duration rice variety *Gayatri* (155 days) under three planting methods of establishment *viz.*, direct seeding, planting normal aged seedlings and planting of aged seedlings at 15x10 cm spacing (66 hills m^{-2}) during *Kharif* season in a sandy loam soil at 60 kg N ha^{-1} revealed that there was reduction in the number of productive tillers per linear meter row due to planting of aged seedlings. However, more number of productive tillers per linear meter row was observed in direct seeded (71.2) as well as in the planting of normal aged seedlings (74.2) (Nayak and Chaudhury, 1997).

Reduction in tillering was also observed at Raipur (Chattisgarh) in a medium duration rice variety (*Kranti*) when older seedlings (50 days) were planted as compared to younger seedlings (30 and 45 days), irrespective of plant spacing or population (20x20, 20x15 and 20x10 cm corresponding to 25,33 and 50 hills m^{-2}) in a sandy loam soil at 80 kg N ha^{-1} during *Kharif* season. This was attributed to concomitant effect of establishment of crop, less tillering period and crop duration in the main field for aged seedlings (Patel, 1999). At Imphal (Manipur), more number of tillers were recorded in 20 days old seedlings and it was on par with that of 27 days old seedlings and the lowest number of tillers were found in 41 and 48 days old seedlings in an experiment conducted during *Kharif* season with a rice variety *Norin 18* at three different plant spacing *viz.*, 20x10, 20x15 and 20x20 cm (50,33,25 hills m^{-2}) with 60 kg N ha^{-1} (Devi and Singh, 2000).

It may be concluded that planting of young seedlings (seedlings of normal age) gave more tillers than old seedlings, irrespective of soil type and N levels. Generally, the number of tillers $hill^{-1}$ was found to decrease with increase in age of seedlings. Direct seeding of rice gave higher number of tillers than transplanting, irrespective of duration of rice varieties, soil types and N levels. The optimum age of seedlings for transplanting depends on duration of crops.

2.1.3. Dry matter production

In field trials at Kapurthala (Punjab), 60 days old seedlings were found to increase the dry matter accumulation over 30 and 45 days old seedlings at different fertilizer levels (0,60,90,120 and 150 kg N ha^{-1}) as observed both during *Kharif* and *Rabi* seasons (Gill and Shahi, 1986). On the contrary, at Bhubaneshwar, the total dry matter production was maximum when four week old seedlings at the rate of five seedlings per hill, were transplanted at 10x15 cm (66 hills m^{-2}) followed by three, two and five week old seedlings with the same number of seedlings per hill and at the same plant density under 60 kg N ha^{-1}. When the number of seedlings per hill was decreased from 5 to 2 $hill^{-1}$, the dry matter also decreased drastically in a rice cultivar *Parijat* during *Kharif* season (Das *et al.*, 1988).

At Rajendra Nagar (Hyderabad), transplanting of 35 days old hybrid rice (*APHR 2*) seedlings resulted in significantly higher dry matter production at all stages of growth over 25 and 45 days old seedlings at 15x15 cm (44 hills m^{-2}) and 15x20 cm spacing (33 hills m^{-2}) with 120 kg N ha^{-1} in a sandy loam soil during *Kharif* season. This was attributed to longer growth period for 35 days old seedlings in the main field than that of 45 days old seedlings and on the other hand 25 days old seedlings though had adequate time for growth and development, recorded low dry matter production as the seedlings were thin and lanky at the time of transplanting (Padmaja and Reddy, 1998).

2.1.4. Yield attributes

2.1.4.1.Productive tillers

The number of productive tillers per linear meter was maximum when seedlings of normal age were planted during wet season in a sandy loam soil at Bhubaneswar (Orissa) in six varieties of rice *viz.*, *Parijat* (95 days), *Sarasa, IR 36, Ratna* (120 days each), *Jajati* (135 days) and *Gayatri* (155 days). Significant reduction in the number of productive tillers was observed when aged seedlings were planted (Nayak and Chaudhury, 1997).

2.1.4.2.Panicle characters

Experiment conducted at Karimganj (Assam) during dry (*ahu*) season (May-June) in a clay loam soil with three popular rice varieties (*Rasi, Cauvery* and *Kalinga-III*) at 20x15 cm spacing (33 hills m^{-2}) at 40 kg N ha^{-1} revealed that among the yield attributing characters, only panicle weight was found to be significantly affected by seedling ages. Planting of 25 days old seedlings recorded the highest panicle weight and it was found to decrease significantly with the increase in seedling age at transplanting. However, panicle weight of 35 and 45 days old seedlings were statistically at par. Other ancillary characters like number of panicles m^{-2} and panicle length were not affected significantly by the age of seedlings. However, both the characters decreased with increase in age of seedlings (Kurmi *et al.*, 1993). On the contrary, at Hyderabad, the age of seedlings was found to have significant effect on yield attributes of rice. Yield attributes such as panicles m^{-2}, panicle length and panicle weight were significantly higher with 45 and 30 days old seedlings than with 60 days old seedlings in a clay loam soil in a short duration rice variety *Rasi* during dry (*Rabi*) season, irrespective of fertilizer N levels *viz.*, 0,40,80,120 and 160 kg ha^{-1} (Singh *et al.*, 1996).

In another study at Rajendra Nagar, yield attributes such as number of panicles m^{-2}, grains per panicle and panicle weight were more when 35 days old seedlings were planted as against 25 and 45 days old seedlings as observed in hybrid rice (*APHR* 2) when planted at 15x15 and 15x20 cm spacing (44 and 33 hills m^{-2}) with 120 kg N ha^{-1} in a sandy clay loam soil during *Kharif* season. This was attributed to longer growth period of 35 days old seedlings over 45 days old seedlings and lankiness of 25 days old seedlings as compared to 35 days old seedlings (Padmaja and Reddy, 1998).

At Faizabad (Uttar Pradesh), planting of 25 days old seedling of rice variety *Sarjoo 52* in silty loam soil during *Kharif* season with 20x10cm spacing (50 hills m^{-2}) led to significant improvement in various yield attributes like panicle number m^{-2} and panicle length over 35 and 45 days old seedlings, irrespective of N levels *viz.*, 40,80 and 120 kg N ha^{-1} (Singh and Singh, 1998). Under late planted conditions at Gangavati (Karnataka), in a black clayey soil, the short duration rice variety *IR 64* gave more number of panicles and more grains per panicle when both 35 and 45 days old seedlings were planted than 25 days old seedlings during *Kharif* season (Channabasappa *et al.*, 1998).

Similarly, in a medium duration rice variety *Kranti*, more number of panicles m^{-2} and grains per panicle were recorded in 30 days old seedlings than that of 40 and 50 days old seedlings at Raipur (Chattisgarh) in a clay loam soil during *Kharif* season at 80 kg N ha^{-1} under three plant spacing *viz.*, 20x10, 20x15 and 20x10 cm (25,33 and 50 hills m^{-2}). The reduction in yield attributes in old seedlings was due to concomitant effect of establishment of crop, lesser tillering period and crop duration in the main field (Patel, 1999).

At Imphal (Manipur), the number of panicles $hill^{-1}$ was found to decrease with increase in the age of seedlings (20,27,34,41 and 48 days) in a rice variety *Norin 18*, irrespective of plant density or spacing (20x10, 20x15, 20x20 cm corresponding to 50,33,25 hills m^{-2}) at 60 kg N ha^{-1} during *Kharif* season (Devi and Singh, 2000).

On the contrary, significantly higher grain weight per hill and more filled grains per panicle were recorded from 35 and 45 days old seedlings than 25 days old seedlings in an experiment with a long duration rice cultivar *Sonamasuri* (140-150 days) at 150 kg N ha^{-1} in a black clayey soil at Gangavati (Karnataka) during *Kharif* season (Pattar *et al.*, 2001).

2.1.4.3.Test weight (1000 grain weight)

Studies at Karimganj (Assam) with *Sali* rice variety (lowland winter rice) at a spacing of 20x15 cm (33 hills m^{-2}) using different age of seedlings (35,45,55 and 65 days) in a clay loam soil during *Rabi* season at three N levels (0,20 and 40 kg ha^{-1}) revealed that the 1000 grain weight decreased significantly due to the delayed planting of 65 days old seedlings and finally resulted in lesser productivity (Choudhary *et al.*, 1997).

The test weight of grains were maximum when seedlings of normal age were planted during wet season in a sandy loam soil at Bhubaneswar (Orissa) in six varieties of rice *viz.*, *Parijat* (95 days), *Sarasa, IR 36, Ratna* (120 days each), *Jajati* (135 days) and *Gayatri* (155 days). Significant reduction in test weight was obtained when aged seedlings were planted (Nayak and Chaudhury, 1997).

Studies at Rajendra Nagar (Andhra Pradesh) revealed that 1000 grain weight was more when 35 days old seedlings were planted as against 25 and 45 days old seedlings as observed in hybrid rice (*APHR* 2) when planted at 15x15 and 15x20 cm spacing (44 and 33 hills m^{-2}) with 120 kg N ha^{-1} in a sandy clay loam soil during *Kharif* season (Padmaja and Reddy, 1998). At Faizabad (Uttar Pradesh), planting of 25 days old seedling of rice variety *Sarjoo 52* in silty loam soil during *Kharif* season with 20x10 cm spacing (50 hills m^{-2}) led to increase in 1000 grain weight over 35 and 45 days old seedlings irrespective of N levels (Singh and Singh, 1998). In a medium duration rice variety *Kranti*, higher 1000 grain weight was recorded in 30 days old seedlings than in 40 and 50 days old seedlings at Raipur (Chattisgarh) in a clay loam soil during *Kharif* season at 80 kg N ha^{-1} irrespective of plant spacing *viz.*, 20x10, 20x15 and 20x10 cm corresponding to 25,33 and 50 hills m^{-2} (Patel, 1999).

2.1.4.4.Grain filling

At Hyderabad, when rice variety *Basmati 370* was planted with 30, 40 and 50 days old seedlings, it was observed that the proportion of chaff and partially filled grains were more with the planting of 50 days old seedlings and the number of filled grains per panicle was more due to planting of 30 days old seedlings (Rao, 1991). Studies at Karimganj (Assam) with *Sali* rice variety (lowland winter rice) at a spacing of 20x15 cm (33 hills m^{-2}) using different age of seedlings (35,45,55 and 65 days) in a clay loam soil during *Rabi* season at three N levels (0,20 and 40 kg ha^{-1}) revealed that the number of filled grains $panicle^{-1}$ decreased significantly due to the delayed planting of 65 days old seedlings. The decrease in this sink component resulted in lesser productivity of delayed planting of 65 days old seedling (Choudhary *et al.*, 1997).

In an experiment conducted at Bhubaneswar (Orissa) in six varieties of rice *viz.*, *Parijat* (95 days), *Sarasa, IR 36, Ratna* (120 days each), *Jajati* (135 days) and *Gayatri* (155 days) in a sandy loam soil during wet season, the older seedlings registered maximum number of fertile spikelets per ear and it decreased progressively with decrease in age of seedlings (Nayak and Chaudhury, 1997).

At Faizabad (Uttar Pradesh), planting of 25 days old seedling of rice variety *Sarjoo 52* in silty loam soil during *Kharif* season with 20x10 cm spacing (50 hills m^{-2})

led to increase in filled grains per panicle over 35 and 45 days old seedlings, irrespective of N levels (Singh and Singh, 1998). Significantly more filled grains per panicle was recorded in 35 and 45 days old seedlings than that of 25 days old seedlings in a long duration rice cultivar *Sonamasuri* (140-150 days) at 150 kg N ha^{-1} in a black clayey soil at Gangavati (Karnataka) during *Kharif* season (Pattar *et al.*, 2001).

It may be summarized that the number of productive tillers, panicles m^{-2}, panicle length and panicle weight decreases with the increase in age of seedlings, irrespective of soil type, climate and nitrogen levels as far as short duration rice varieties are concerned. However, planting of very young seedlings also results in reduced yield attributes such as number of panicles m^{-2}, panicle weight and 1000 grain weight due to lankiness. In long duration varieties, planting of older seedlings sometimes found to give improved yield attributes than the young seedlings. Hence there is a need to identify the optimum age of seedlings for short, medium and long duration varieties seperately according to the local situation.

2.1.5. Yield

2.1.5.1.*Kharif* season

2.1.5.1.2. Medium black soil

At Jabalpur, rice variety *JR 25-423-2-L* planted with different ages of seedlings (20,28 and 36 days old) revealed that grain yields were affected significantly by the age of seedlings used for transplanting. Planting of 20 days old seedlings resulted in maximum yield as compared to that of 36 days old seedlings. When transplanting was delayed, the decrease in yield due to use of aged seedlings ranged from 4 to 16 per cent (Koshta *et al.*, 1987).

2.1.5.1.2.Clay loam soil

At Dapoli (Maharastra), an experiment with rice cultivar *R 711* under three ages of seedlings (25, 35 and 45 days old) revealed that transplanting of 25 days old seedlings produced significantly higher grain yield than that of 35 and 45 days old seedlings, irrespective of plant spacing *viz.*, 15x10, 15x15 and 15x20 cm (66, 44 and 33 hills m^{-2}) and N levels *viz.*, 75, 100 and 125 kg ha^{-1} (Wagh *et al.*, 1988).

At Raipur (Chattisgarh), in a medium duration rice variety *Kranti* planted with 30, 40 and 50 days old seedlings, it was observed that grain yield was significantly higher with planting of 30 days old seedlings than that of 40 and 50 days old seedlings, irrespective of plant density *viz.*, 20x10, 20x15 and 20x20 cm (50, 33 and 25 hills m^{-2}). The straw yield also followed similar trend (Patel, 1999).

2.1.5.1.3.Sandy loam soil

A field trial at Bhubaneswar with six varieties of rice *viz.*, *Parijat* (95 days), *Sarasa, IR 36, Ratna* (120 days each), *Jajati* (135 days) and *Gayatri* (155 days) and three ages of seedlings (direct sown, normal age and aged seedlings) revealed that there was reduction in grain yield due to planting of aged seedlings when compared to normal aged seedlings at same plant density and N level (15x10 cm spacing with 66 hills m^{-2} at 60 kg N ha^{-1}). But the interaction between variety and age of seedling revealed that maximum yield was obtained with aged seedlings in long duration rice variety (Gayatri-155 days) and in other varieties maximum yield was recorded with normal seedlings. Similar trend was also observed in case of straw yields (Nayak and Chaudhury, 1997).

2.1.5.1.4.Sandy clay loam soil

The grain yield of rice hybrid (*APHR* 2) was significantly higher when transplanted with 35 days old seedlings than 25 and 45 days old seedlings at Hyderabad, irrespective of plant spacing *viz.*, 15x15 and 15x20 cm (44 and 33 hills m^{-2}). This was attributed to longer growth period of 35 days old seedlings (10 days) in the main field over 45 days old seedlings and the low yield in 25 days old seedling was due to thin and lankiness of seedlings at the time of transplanting (Padmaja and Reddy, 1998).

2.1.5.1.5.Silty loam soil

At Faizabad (Uttar Pradesh), planting of rice variety *Sarjoo 52* with 25, 35 and 45 days old seedlings at 20x10 cm spacing (50 hills m^{-2}) revealed that transplanting of 25 day old seedlings recorded significantly the highest grain and straw yields, irrespective of N levels *viz.*, 40, 80 and 120 kg N ha^{-1} (Singh and Singh, 1998).

2.1.5.1.6.Black clayey soil

Investigation carried out at Gangavati (Karnataka) with 25, 35 and 45 days old seedlings of short duration *IR 64* rice variety revealed that under late planted condition (14 and 26 August) both 35 and 45 days old seedlings perfomed better and gave significantly higher grain yield than 25 days old seedlings, irrespective of N levels (100,125 and 150 kg ha^{-1}). However, rice planted with 45 days old seedlings showed only marginal increase in yield over 35 days old seedlings (Channabasappa *et al.*, 1998). In the same location (Gangavati) at same season, similar results were obtained in a long duration rice variety (*Sonamasuri* 140-150 days) i.e., 35 or 45 days old seedlings gave higher yields than 25 days old seedlings (Pattar *et al.*, 2001).

2.1.5.1.7.Other soils

At Cuttack (Orissa), there was significant difference in grain yield between four photosensitive rice varieties (*viz.*, *IET 12875, Lunisree, CR 629 -256 and CR 683-195*) when 30 and 45 days old seedlings were planted. However, the grain yield was marginally more in 45 days old seedlings as compared to 30 days old seedlings (Krishnan and Nayak, 1997).

Varietal variation had been observed in respect of yield as influenced by age of seedlings. Neither very young seedlings of 20 days old nor older seedlings of 34, 41 and 48 days old gave higher grain yield in respect of *Norin 18* rice variety at 60 kg N ha^{-1}, irrespective of plant spacing *viz.*, 20x10, 20x15 and 20x20 cm (50, 33 and 25 hills m^{-2}). But 27 days old seedling of this variety gave the highest grain yield at Imphal (Manipur). However, the highest straw yield was recorded with 20 days old seedlings. This was due to the advantage of early establishment, high tillering and vigorous growth attainable by the younger seedlings (Devi and Singh, 2000).

It is inferred from the above review that during *Kharif* season, the optimum age of seedlings for higher yields varies from 20-35 days for short duration rice varieties in different soil types irrespective of plant density, N levels and geographical locations (climate). However, for long duration rice varieties such as *Sonamasuri* and *Gayatri* (140-150 days) the optimum age of seedlings seems to be 35 to 45 days old in different soil types, irrespective of plant density, N levels and geographical locations.

2.1.5.2.*Rabi* season

In a medium duration rice variety (*IR 20*), the grain yield decreased with increase in seedling age from 25 to 45 days in a clay loam soil at Coimbatore (Manoharan and Subramanian, 1983). At Aduthurai (Tamil Nadu), evaluation of rice varieties for late planting situation revealed that transplanting of aged seedlings (40, 50 and 60 days old) affected grain yield in general. Rice culture *IET 7590* recorded the highest grain yield of 8.6 t ha^{-1} when 40 days old seedlings were planted as compared to other varieties tested in a clay loam soil (TRRI, 1987).

At Joydebpur (Bangladesh) when 30, 40 and 60 days old seedlings of rice varieties (*BR 11, BR 22, BR 23* and *Nizersail*) were evaluated during *aman* (winter) season in a clay loam soil, it was observed that transplanting 30 to 60 days old seedlings had no significant effect on grain yield of *BR 11*, *BR 22* and *Nizersail*. But in *BR 23*, the grain yield was the highest with 45 days old seedlings (Mannan and Siddique, 1990).

Studies at Warangal (Andhra Pradesh) in a clay loam soil with three ages of seedlings (30, 45 and 60 days) revealed that grain yields were the highest with 30 days old seedlings and the lowest with 60 days old seedlings. Straw yield was significantly higher when the seedlings were transplanted at 30 days, whereas it was significantly lower when the seedlings were transplanted at the age of 60 and 45 days with 100 kg N ha^{-1}, irrespective of plant population *viz.*, 44 and 100 hills ha^{-1} (Reddy and Reddy, 1991). On the contrary, at Bangladesh, when 30, 45, 60 and 75 days old *aman* rice seedlings (*BR 11*) were transplanted, the grain yield was higher in 60 and 75 days old seedlings. Gross return, gross margin and benefit cost ratio were also the highest with planting of 75 days old seedlings (Ali *et al.*, 1995).

At DRR farm (Hyderabad), when short duration rice variety *Rasi* (115 days) was transplanted with three different aged seedlings (30, 45 and 60 days) in a clay loam soil, the maximum grain yield was obtained with 45 days old seedlings closely followed by 30 day old seedlings, irrespective of N levels (0, 40, 80, 120 and 160 kg N ha^{-1}). Significantly lower grain yield was recorded with 60 days old seedlings as compared to that of 30 and 45 days old seedlings (Singh *et al.*, 1996). Constantly better grain yield was recorded in 45 days old seedlings at 20x15 cm spacing (33 hills m^{-2}) and it was also comparable with that of 35 and 55 days old seedlings as observed in *Andrewsali* rice variety at Assam (Thakuria *et al.*, 1999).

It is inferred that during *Rabi* season which coincides with winter the optimum age of seedlings ranges from 30 to 45 days for medium and short duration rice varieties, irrespective of plant density, N levels and geographical locations (climate). However, in long duration rice varieties, 45 to 60 days old seedlings were found to give fairly high yield irrespective of plant density, N levels and geographic locations (climate).

2.1.6. Quality

A field experiment conducted at Faizabad (Uttar Pradesh) during rainy season (*Kharif*) in a silty loam soil using rice variety *Sarjoo 52* with 3 ages of seedlings (25, 35 and 45 days) at 20x10 cm spacing (50 hills m^{-2}) revealed that the protein content and protein production were found to reduce with an increase in age of seedlings and were the highest with the use of young seedlings for transplanting, irrespective of N levels (40, 80 and 120 kg ha^{-1}). The higher protein yield with young age of seedlings were due to higher grain and straw yields (Singh and Singh, 1998).

2.1.7. Crop duration

In a field trial conducted during wet season with six rice varieties of different crop durations *viz.*, *Parijat* (95 days), *Sarasa*, *IR 36*, *Ratna* (120 days each), *Jajati* (135 days) and *Gayatri* (155 days) with three ages of seedlings (direct seeding, normal age and aged seedlings) at 15x10 cm spacing (66 hills m^{-2}) in a sandy loam soil at Bhubaneswar (Orissa), it was observed that the duration of rice crop got reduced when aged seedlings were planted because of shortening of vegetative phase. The varieties matured 1-6 days early due to the use of aged seedlings. The results were in corroboration with the findings of Nayak *et al* (1994) who reported 14-15 days decrease in duration of late duration varieties due to late planting of aged seedlings at Kalyani (West Bengal). The reduction in duration was attributed to reduction in lag-vegetative phase of the photosensitive varieties (Nayak and Choudhary, 1997).

On the contrary, studies conducted at CRRI, Cuttack (Orissa) during wet season (July-December) in photosensitive rice varieties planted with 30 and 45 days old seedlings, it was observed that seedling age did not affect the total crop duration (Planting to harvest) of the photosensitive rice varieties *viz.*, *IET 12875, Lunisree, CR 629-256 and CR 683-195* (Krishnan and Nayak, 1997).

2.1.8. Pest and disease incidence

At Kalyani (West Bengal), the spread of tungro disease was found to increase with increasing age of seedlings and it was maximum at 40 days old seedlings when compared to 25 days old seedlings (Tarafder *et al.*, 1980). Evaluation of 25 and 50 days old seedlings of 32 rice varieties at Pusa (Bihar), for natural infestation by *Saracladium oryzae* (Sheath rot fungus) revealed that its occurrence was high in 50 days old seedlings. Photosensitive tall varieties were more resistant than photoinsensitive varieties (Singh *et al.*, 1986).

2.2. Plant density

A uniform crop stand with optimum plant density is essential for proper crop development and high grain yields (Nguu and De Datta, 1979). Mutual shading occurs within the hills under wider spacing because of more number of tillers hill^{-1} and between hills under closer spacing (Pothiraj *et al.*, 1977). Mutual shading affects photosynthesis and other physiological activities of plants adversely. Hence, optimum spacing is determined by many factors such as tillering habit of the variety, soil fertility and fertilizer management, cultural practices and climatic conditions. A generalized recommendation of spacing for all rice varieties and all situations is not possible (Panda *et al.*, 1972). It is, therefore desirable to adjust plant spacing for achieving high yields under different set of conditions. Manipulation of planting geometry appears to have a promising potential for increasing the rice yield, as it is assumed to have pronounced effect on tillering, interception and utilization of light which in turn influences rice yield (Alexander *et al.*, 1988).

2.2.1. Growth attributes

2.2.1.1. Plant height

A field experiment conducted at Madurai (Tamil Nadu) during *Kharif* and *Rabi* seasons in a sandy clay loam soil using short duration rice variety (*ADT 36*) under two plant densities 66 hills m^{-2} (15x10 cm spacing) and 83 hills m^{-2} (15x8 cm spacing) revealed that closer planting with 83 hills m^{-2} resulted in taller plants with longer leaves when compared to wider spacings irrespective of N levels *viz*., 100, 150 and 200 kg ha^{-1} (Kandasamy and Ramasamy, 1998). On the contrary, it was observed in rice cultivar *Jinongda 7* that plant height decreased significantly at narrow spacing of 30x13.2 cm (25 hills m^{-2}) as compared to wider plant spacing of 30x39.6 cm (8 hills m^{-2}) and 30x19.8 cm (17 hills m^{-2}) (Yang Fu *et al.*, 2001).

2.2.2. Leaf area index and drymatter accumulation

At Rajendra Nagar, Hyderabad, the rice hybrid *APHR 2* transplanted at a closer spacing of 15x15 cm (44 hills m^{-2}) was found to produce significantly higher DMP m^{-2} than that of wider spacing of 15x20 cm (33 hills m^{-2}) at all stages of crop growth, irrespective of age of seedlings (25,35 and 45 days old) at 120 kg N ha^{-1} in a sandy clay loam soil during *Kharif* season (Padmaja and Reddy 1998). At Madurai (Tamil Nadu) also, a medium duration hybrid rice (*CORH 2*) registered higher dry matter production at higher plant density of 50 hills m^{-2} (20x10 cm) and it was higher than that of lesser plant densities of 33 hills m^{-2} (20x15 cm) and 25 hills m^{-2} (20x20 cm) during *Rabi* (*Samba*) season in a sandy clay loam soil when 25 days old seedlings were planted, irrespective of N levels *viz*., 150,200 and 250 kg ha^{-1} (Rajarathinam and Balasubramaniyan, 1999).

Similarly, the highest DMP was obtained at Madurai (Tamil Nadu) during both *Kharif* and *Rabi* seasons in a sandy clay loam soil when 26 days old seedlings of short duration rice variety (*ADT 36*) was planted at high plant density of 83 hills m^{-2} with closer spacing of 15x8 cm as compared to low plant density of 66 hills m^{-2} with wider spacing of 15x10 cm at 100,150 and 200 kg N ha^{-1}. More number of hills per unit area resulted in taller plants with longer leaves under high plant density of 83 hills m^{-2} and hence the LAI was also more in both the seasons at the highest plant population as compared to lower plant density and wide spaced crop (Kandasamy and Ramasamy, 1998).

In general, planting density was found to influence DMP very much than planting geometry. Studies conducted at Aliyar Nagar (Tamil Nadu) during *Rabi* season in a sandy loam soil with 30 days old seedlings of three medium duration rice varieties (*IR 20*, *ADT 38* and *CO 45*) with four spacings of 20x10 cm, 14.1x14.1 cm (50 hills m^{-2}) and 20x15 cm, 17.4x17.4 cm (33 hills m^{-2}) revealed that planting density of 50 hills m^{-2} recorded higher DMP over 33 hills m^{-2} at 150 kg N ha-1, irrespective of planting geometry. (Though DMP recorded in individual plant (hill) was higher at wider spacing, due to the presence of lesser number of hills per unit area the DMP ha^{-1} was lower at wider spacing (Lourduraj and Rajagopal, 1999).)

Evaluation of five *Basmati* rice cultivars at three plant densities during the wet season on clay loam soil in the new alluvial zone of West Bengal revealed that growth attributing characters like LAI, dry matter accumulation and CGR were significantly influenced by different spacings/plant densities. Among the five cultivars *Pusa Basmati* recorded the highest growth attributing characters such as LAI, dry matter accumulation and CGR at a closer spacing of 10x15 cm (Ray *et al.*, 2001). Similar trend was observed in respect of LAI in rice cultivar *Jinongda 7* when evaluated under different plant densities by Yang Fu *et al.* (2001).

The above literature have clearly shown that irrespective of soil types, seasons and genotypes (hybrid/variety), age of seedlings, N levels and geographical locations, the LAI and DMP were found to increase at high plant density with closer plant spacing.

2.2.3. Nutrient uptake/accumulation

A field experiment conducted at Warangal with two plant densities (44 and 100 hills m^{-2}) revealed that N uptake was higher in grains at low plant density but more in straw at high plant density, irrespective of age of seedlings (30,40 and 60 days) with 100 kg N ha^{-1} during *Rabi* season. The total accumulation of P (grain + straw) at harvest was significantly higher at higher plant density than at lower density. However, it was higher in grain than in straw. Similarly, accumulation of K was greater in grain at high plant density than in low density (Reddy and Reddy, 1991).

Studies conducted at Madurai (Tamil Nadu) during *Rabi* season in a sandy clay loam soil with medium duration rice hybrid (*CORH 2*) with three plant population (50, 33 and 25 hills m^{-2}) revealed that planting of 25 days old seedlings at 50 hills m^{-2} significantly increased the N uptake than 33 and 25 hills m^{-2} at all the three levels of N (150,200 and 250 kg N ha^{-1}). This was attributed to the accumulation of more dry matter at 50 hills m^{-2}. Plots that were planted with 25 hills m^{-2} had high post harvest N status than plots having 30 and 50 hills m^{-2} (Rajarathinam and Balasubramaniyan, 1999).

Similarly, in a field experiment conducted at Aliyar Nagar during *Rabi* season in a sandy loam soil using 30 days old seedlings of medium duration rice varieties (*IR 20*, *ADT 38* and *CO 45*) with a spacing of 20x10 cm, 14.1x14.1 cm (50 hills m^{-2}) and 20x15 cm; 17.4x17.4 cm (33 hills m^{-2}) at 150 kg N ha^{-1} revealed that plant population as well as planting geometry influenced the nitrogen and phosphorous uptake significantly. Higher nutrient uptake was recorded under higher population level of 50 hills m^{-2} than at 33 hills m^{-2}, which was attributed to higher biomass production under closer spacing. Planting geometry and plant population were found to influence the soil available P but not the available N as observed in the post harvest soil analysis. Soil available P was higher under low density planting of 33 hills m^{-2} as compared to 50 hills m^{-2}. This was attributed to lesser P uptake under wider planting and comparatively lesser loss of this nutrient from the soil which resulted in increased soil available P. The soil available K also followed the same trend as that of soil available P (Lourduraj and Rajagopal, 1999).

Field trials conducted at five farmer's holdings in Irugur soil series of Erode district (Tamil Nadu) with two population densities (60 hills m^{-2} and 80 hills m^{-2}) in three medium duration rice varieties (*ADT 38*, *ASD 19* and *ADT 39*) revealed that application of higher doses of N with high plant population of 80 hills m^{-2} recorded higher N uptake when N was applied at 108 – 278 kg ha^{-1} on STCR basis for an yield target of 6,7 and 8 t ha^{-1}. This was attributed to the better utilization of added N. The increase of root foraging area under higher population density might have resulted in higher N uptake and consequently resulted in the efficient utilization of added N. The increase in plant density upto 80 hills m^{-2} for short or medium duration varieties in light textured soils was found to increase the efficiency of added N (Santhi *et al.*, 2000).

Nitrogen concentration and total N uptake by rice crop were found to be influenced by applied N and planting density as observed at panicle initiation and maturation stages during the wet season in Gazipur (Bangladesh). Evaluation of rice cultivar *IPK 37008* at four N levels (0,40,80 and 160 kg ha^{-1}) and three planting densities (20, 40 and 80 hills m^{-2}) revealed that the effect of applied N on plant N concentration was greater than that of plant density. The plant density did not cause significant variation in N uptake by rice at any growth stage (Khanam *et al.*, 2000).

2.2.4. Weed population

Weed population was found to increase as the plant spacing increased from 10x10 cm to 40x40 cm at 80 and 160 kg N ha^{-1} during wet season at Allahabad when 31 days old seedlings of rice varieties *Ratna* and *Saket 1* were planted (Agasimani *et al.*, 1983). Field experiments conducted during *Rabi* season at Aliyar Nagar (Tamil Nadu) in a sandy loam soil with three rice cultivars (*IR 20*, *ADT 38* and *CO 45)* under two plant populations *viz.*, 50 hills m^{-2} (20x10 cm and 14.1x14.1 cm) and 33 hills m^{-2} (20x15 cm and 17.4x17.4 cm) using 30 days old seedlings revealed that weed count and weed dry weight were higher under wider planting with 33 hills m^{-2} as compared to closer planting with 50 hills m^{-2} at 150 kg N ha^{-1}. This was attributed to availability of more land area between two rice hills under wider spacing, which facilitated weed emergence, and growth. In case of closer planting, the rice seedlings would have exercised a smothering effect reducing weed number and dry weight (Lourduraj *et al.*, 2000).

2.2.5. Quality attributes

Studies on distribution of high density grains (HDG) in the top, middle and bottom portions of panicles of rice cultivars (*Sabita* and *Utkalprabha)* under different plant densities at Kolkata during wet season revealed that the number of HDG decreased with increased plant population (narrow spacing). The wider spacing resulted in better grain filling due to lesser competition among the plants for light, space, water and nutrition. The HDG was significantly higher in both the varieties mainly in the upper part of the panicle and the number of HDG was greater in secondary than in primary rachis branches (Saha, 2000). Observations at west Bengal in a clay loam soil during rainy season (*Kharif*) with five *Basmati* rice cultures revealed that planting at wider spacing of 20x15 cm (33 hills m^{-2}) gave better rice quality than planting at closer spacing of 15x15 cm (44 hills m^{-2}) (Ray *et al.*, 2001).

2.2.6. Yield attributes and yield

2.2.6.1.Clay loam soil

In a field experiment conducted with a short duration rice variety (*ADT 36*) at Aduthurai (Tamil Nadu) under three spacing (12.5 x10cm with 80 hills m^{-2}, 15x10 cm with 66 hills m^{-2} and 20x10 cm with 50 hills m^{-2}) with 75 kg N ha^{-1}, when 60 days old seedlings were used for transplanting in dry season, it was observed that the number of tillers per hill increased with wider spacing. But the number of tillers per unit area was the highest with the closer spacing of 15x10cm. Inspite of reduced tillers $hill^{-1}$, panicle weight and number of filled spikelets $panicle^{-1}$, planting at closer spacing of 12.5x10 cm with 80 hills m^{-2} produced significantly higher grain yield because of higher number of tillers per unit area (Ramasamy *et al.*, 1987).

Field trials at Dapoli (Maharastra) during wet seasons (*Kharif*) with three spacings (15x10, 15x15 and 15x20 cm corresponding to 66,44 and 33 hills m^{-2}) revealed that different densities of planting did not influence the grain yield of medium duration rice variety (*R 711*), irrespective of age of seedlings (25,35 and 45 days old) and N levels (75,100 and 125 kg ha^{-1}), probably due to the better tillering capacity of the variety with the wider spacing which compensated for the yield produced with closer spacing of 15x10 cm (Wagh *et al.*, 1988). Yield maximization trials at Aduthurai (Tamil Nadu) revealed that closer spacing of 12.5x10 cm (80 hills m^{-2}) had registered maximum grain yield of 4.5 t ha^{-1} which was on par with very narrow spacing of 10x10 cm (100 hills m^{-2}) that gave 4.3 t ha^{-1} (TRRI, 1989).

In a field experiment conducted at Coimbatore with a short duration rice variety *ADT 36*, under three plant densities *viz.*, 80 (12.5x10cm), 66(15x10cm) and 50(20x10cm) hills m^{-2}, there was reduction in the number of productive tillers $hill^{-1}$ due to increased plant density (80 hills m^{-2}) as compared to 66 and 50 hills when 60 days old seedlings were used, irrespective of N levels (0,100 and 125 kg ha^{-1}) during dry season (Dec-March). But the reduction was not phenomenal. The number of filled grains $panicle^{-1}$ was found to decrease with increase in plant density. In contrast, the number of panicles m^{-2} was higher when density was increased to 80 hills as compared to the recommended practice of planting 66 hills m^{-2}. This increase in panicles m^{-2} reflected on yield. Whereas, the yield got decreased when plant spacing was widened (20x10 cm) to accommodate only 50 hills m^{-2} (Ramasamy and Babu, 1997).

At Raipur, it was further confirmed that rice hybrid *(6201)* as well as variety (*Kranti*) putforth more number of effective tillers m^{-2} when closely planted at 15x10 cm spacing (66 hills m^{-2}) as compared to wider spacings of 20x15 (33 hills m^{-2}) and 20x10 cm (50 hills m^{-2}) when 32 days old seedlings were planted with 100 kg N ha^{-1}, during *Kharif* season. The variety (*Kranti*) and hybrid (*6201*) registered more number of filled grains $panicle^{-1}$, panicle length, panicle weight and 1000 grain weight which resulted in higher grain yield at higher plant density of 66 hills m^{-2} than at lower plant density of 50 hills m^{-2} and 33 hills m^{-2} (Shrivastava *et al.*, 1999).

In an another field experiment at Raipur during *Kharif* season with medium duration rice variety *Kranti* (130 days), it was observed that tiller number m^{-2} reduced by adoption of wider spacing of 20x15cm (33 hills m^{-2}) and 20x20 cm (25 hills m^{-2}) as compared to closer spacing of 20x10 cm (50 hills m^{-2}), irrespective of age of seedlings (30, 40 and 50 days) at 80 kg N ha^{-1}. The higher plant population was found to give not only higher grain yield but also higher straw yield. Closer spacing of 20x10cm (50 hills m^{-2}) recorded significantly higher grain and straw yields than the wider spacings. The number of panicles m^{-2} also followed similar trend. However, grains $panicle^{-1}$ and test weight were not influenced by spacings (Patel, 1999). It was further established beyond doubt in yet another field experiment at Raipur that the effective tillers were significantly more in closer spacing (10x10 cm spacing with 100 hills m^{-2}) as compared to wider spacing (20x10 cm; 50 hills m^{-2}), irrespective of N levels (80and120 kg ha^{-1}) as observed in four medium duration rice varieties (*Mahamaya*, *Kranti*, *R-296-260* and *Suraksha*). Doubling of plant population with very closer spacing of 10x10 cm (100 hills m^{-2}) produced significantly higher grain yield over wider spacing of 20x10 cm (50 hills m^{-2}). This indicated that rice varieties are highly plastic and higher plant population mostly results in higher yield (Siddiqui *et al.*, 1999).

On the contrary, the trend was quite different in fine rice variety (*Pusa Basmati 1*) during rainy (*Kharif*) season at Kamal (Haryana) under three spacings (15x15, 20x15 and 30x15 cm) which revealed that seed weight $panicle^{-1}$, length of panicle and 1000 grain weight were not influenced by different spacings when 35 days old seedlings were planted, irrespective of N levels (0,40,80 and 120 kg ha^{-1}). However, wider spacing of 20x15 cm (33 hills m^{-2}) and 30x15 cm (22 hills m^{-2}) recorded significantly higher number of panicles $plant^{-1}$ than the narrower spacing of 15x15 cm (44 hills m^{-2}). The seed and straw yields were not significantly different due to different spacings (Chopra and Chopra, 2000).

2.2.6.2.Sandy loam soil

Higher grain yields were obtained with higher plant population during wet season in *Mahanadi* delta in Orissa, when long duration rice variety *CR 1018* (155 days) was planted at different plant population of 20,25,33 and 44 hills m^{-2}, irrespective of age of seedlings (30 and 60 days old). However, the population of 33 hills m^{-2} (20x15 cm) was found optimum as it was on par with 15x15 cm spacing with 44 hills m^{-2} (Chandra and Manna, 1988).

Moreover, it was found that at any given plant density, the rice yield was not influenced by crop geometry. Observations at Aliyar Nagar (Tamil Nadu), during *Rabi* season with medium duration rice varieties (IR 20, ADT 38 and *CO 45*) at a plant density of 50 hills m^{-2} (20x10 cm and 14.1x14.1 cm) and 33 hills m^{-2} (20x15 cm and 17.1x17.1 cm) revealed that planting geometry did not influence the rice yield when 30 days old seedlings was used at 150 kg N ha^{-1} (Lourduraj and Rajagopal, 1999).

2.2.6.3.Sandy clay loam soil

At Chiplima (Orissa), studies during the dry season, in rice variety *Jaya* under two spacing (15x10 cm and 30x10 cm corresponding to 66 and 33 hills m^{-2}) revealed that effective tillers per unit area increased significantly due to closer spacing when 30 days old seedlings were used for planting, irrespective of N levels (0,50,100 and 150 kg ha^{-1}). Closer spacing of 15x10 cm (66 hills m^{-2}) was found to give higher grain yield than at wider spacing of 30x10 cm (33 hills m^{-2}). The straw yield also increased significantly due to closer spacing. Whereas, the length of the panicle and number of grains per panicle were significantly reduced at closer spacing (Gulati *et al.*, 1987).

The optimum plant density for attaining high grain yield was found to differ in rice varieties according to the season (climate) of cropping. Studies at Madurai (Tamil Nadu) with 26 days old seedlings of short duration rice variety (*ADT 36*) at 100, 150 and 200 kg N ha^{-1} during *Kharif* and *Rabi* seasons under two plant densities (66 hills m^{-2} and 83 hills m^{-2}) revealed that varying plant densities did not influence the number of panicles m^{-2} in *Kharif* season, while more number of panicles m^{-2} were produced under low plant density during *Rabi* season. The magnitude of change in grain yield as a function of plant density was quite small in *Kharif* season, whereas it was very obvious during *Rabi* season. Planting of 66 hills m^{-2} (low plant density) recorded higher grain yield during *Rabi* season. This was attributed to the mutual shading under high density planting leading to decreased light transmission into the canopy upsetting the photosynthesis (Kandasamy and Ramasamy, 1998).

Field experiments conducted at Madurai (Tamil Nadu) with three plant densities of 10x10, 12.5x10 and 15x10 cm (100,80 and 66 hills m^{-2}) using short duration rice variety *ADT 36* in *Kharif* and medium duration rice variety *CO 43* in *Rabi* seasons revealed that closer plant spacing 10x10 cm (100 hills m^{-2}) recorded relatively higher grain and straw yields during *Kharif* season, while plant spacing of 12.5x10 cm (80 hills m^{-2}) gave maximum grain yield during *Rabi* season. During both the seasons, the highest harvest indices were obtained under wider espacement (Chandrasekaran *et al.*, 2002).

The yield attributes as well as the grain yield of rice hybrids were also found to be better at higher plant density than at lower plant density. Studies at Hyderabad in rice hybrid (*APHR 2*) during the wet season revealed that the crop planted with 15x15cm (44 hills m^{-2}) resulted in more panicles m^{-2} and gave significantly higher grain yield than at 15x20 cm spacing (33 hills m^{-2}), irrespective of age of seedlings (25,35 and 45 days old) at 120 kg N ha^{-1}. However, heavier panicles were observed at low plant density mainly due to minimum competition for growth among the plants and adequate availability and uptake of nutrients for effective grain filling as compared to closer spacing (Padmaja and Reddy, 1998).

In field experiments conducted during *Rabi* season at Madurai (Tamil Nadu) with rice hybrid CORH 2 under two plant population of 50 hills m^{-2} (20x15 cm) and 25 hills m^{-2} (20x20 cm) revealed that adoption of higher plant density (50 hills m^{-2}) gave significantly higher grain yield than low density (25 hills m^{-2}). Yield attributes such as panicles m^{-2}, panicle weight, panicle length, grains parricle^{-1} and filled grains panicle^{-1} were more at higher plant population of 50 hills m^{-2} (Rajarathinam and Balasubramaniyan, 1999).

At Chiplima (Orissa), when four rice varieties (*Sankar*, *Parijat*, *Lalat* and *Birupa*) of various durations (80,100,125 and 135 days, respectively) were evaluated under three spacings (10x10 cm, 15x10 cm and 20x10 cm with 100,66 and 50 hills m^{-2}) in a clay loam soil, it was observed that effective tillers per hill was significantly influenced by the different plant spacings. Effective tillers per hill increased significantly with wider spacing. The number of panicles m^{-2} decreased with wider spacing. Closer spacing of 10x10 cm (100 hills m^{-2}) recorded significantly lower number of grains panicle^{-1} than the other two wider spacings. The yield attributes such as panicle length, panicle weight and 1000 grain weight were not influenced by spacing. Significantly higher grain and straw yields were recorded with 10x10 cm spacing (100 hills m^{-2}) than at other spacings. The interaction between varieties and spacings was also significant. The short duration rice varieties gave the best results at 10x10 cm (100 hills m^{-2}). But in case of medium duration varieties there was no significant difference between different spacings (Patra and Nayak, 2001).

2.2.6.4.Clay soil

One third increase in plant population by planting the crop at 15x10 cm (66 hills m^{-2}) gave significantly higher grain yield of rice than that of planting at 20x10 cm (50 hills m^{-2}) at Raipur in a clay soil with medium duration rice variety *Kranti* at 120 and 160 kg N ha^{-1} (Pandey and Tripathi, 1993).

2.2.6.5.Other soils

At Warangal (Andra Pradesh), high plant density (100 hills m^{-2}) with application of 100 kg N ha^{-1} in 2 or 3 equal splits gave significantly higher yields of grain and straw than at low plant density (44 hills m^{-2}) at the same level of N, irrespective of age of seedlings *viz.*, 30,40 and 60 days old (Reddy and Reddy, 1991). In the same field experiment at Warangal, under high plant densities the spikelet sterility per cent was high and the harvest index was high in low population densities. Closer spacing resulted in early flowering due to less number of tillers having restricted growth unlike in wider spacing. Similarly the crop duration was increased in wider spacing than in closer spacing. The increase in spikelet sterility in closer spacing was attributed to more competition for photosynthates among plants in a unit area (Reddy and Reddy, 1992).

Some of the rice varieties were found to be dynamic in compensating grain yield even at wider spacing with lower plant density by producing more number of tillers. At Mudigere (Karnataka), performance of two rice varieties *Intan* and *DWR 4107* under five plant densities (30, 35,40,45 and 50 hills m^{-2}) with 75 kg N ha^{-1} during *Kharif* season revealed that there was significant increase in the number of tillers per plant with wider spacing (30 hills m^{-2}) as compared to other narrow spacings. Thus, wider spacing between hills had resulted in higher tillering and it was found to compensate for reduced hills. The grain yield obtained from the recommended population of 50 hills m^{-2} was not significantly different from that produced by 30,35,40 and 45 hills m^{-2}, indicating that a similar grain yield could be obtained by adopting wider spacing, accommodating as few as 30 hills m^{-2}. Also there was significant increase in panicles per plant and a significant decrease in grain weight due to wider spacing (30 hills m^{-2}) as compared to narrow spacing (50 hills m^{-2}) (Jagannath *et al.*, 1998).

The beneficial effect of higher plant density coupled with N fertilizer as per STCR approach was demonstrated in three medium duration rice varieties (*ADT 38*, *ASD 19* and *ADT 39*) through field experiments in five farmer's holdings in Irugur soil series of Erode district (Tamil Nadu). The plant population of 80 hills m^{-2} recorded significantly higher grain and straw yields as compared to 66 hills m^{-2} (Santhi *et al.*, 2000). In a field study at Imphal (Manipur) during the wet season (*Kharif*) using rice variety *Norin 18* it was observed that the highest number of tillers per hill was recorded with the widest spacing of 20x20 cm (25 hills m^{-2}) as compared to closer spacing of 20x10 and 20x15 cm (50 and 33 hills m^{-2}), irrespective of age of seedlings (20,27,34,41 and 48 days) with 60 kg N ha^{-1}. Decrease in number of panicles hill $^{-1}$ was observed under closer spacing due to the tiller mortality caused by mutual shading during preflowering stages of the crop. However, maximum grain yield was recorded at closer spacing of 20x10 cm (50 hills m^{-2}). Further increase in spacing to 20x15 cm (33 hills m^{-2}) 20x20 cm (25 hills m^{-2}) decreased the yield. The closer spacing also resulted in the maximum straw yield. There was no significant difference in grain: straw ratio due to plant density (Devi and Singh, 2000).

On the contrary, evaluation of five *Basmati* rice varieties in West Bengal with three spacing during the wet season in the new alluvial zone revealed that the highest grain yield was recorded under closer spacing of 10x15 cm (66 hills m^{-2}) (Ray *et al.*, 2000). Studies on rice cultivar *Jinongda 7* with different plant densities revealed that with decreasing plant densities the number of tillers and leaves per hill increased and the growth period was extended (Yang Fu *et al.*, 2001).

Dense planting is an important cultural technique for increasing the number of rice spikelets per unit area. It is considered to be favourable for grain filling because it increases the percentage of spikelets that are on the primary rachis branches. Analysis of the relationship between planting density and spikelets number with reference to the percentage of spikelets on the primary rachis branches in an actively tillering rice cultivar *Nipponbare* at four planting densities (11.1,22.2,33.3 and 44.4 hills m^{-2}) combined with four rates of nitrogen top dressing (0-7.5 g m^{-2}) at PI stage revealed that dense planting increased the number of differentiated and final spikelets. The effect of dense planting on spikelet number was more prominent as the rate of N applied at panicle initiation was increased. The dense planting increased panicle number per unit area but decreased the number of differentiated primary rachis branches per panicle. The dense planting does not necessarily increase the percentage of spikelets on primary rachis branches (Kobayasi *et al.*, 2001).

Field studies in China with rice cultivar *Lianyoupeijiu* transplanted at a density of 22.5, 27.0 and 31.5x10^4 holes hm^{-2} with 0,112.5, 225.0 and 327.5 kg N hm^{-2} revealed that effect of plant density was higher on panicle number per unit area and grain number per panicle than on seed setting rate or 1000 grain weight. Yield was not affected by density (Kewu *et al.*, 2001).

From the above review it is concluded that during *Kharif* season, for the short duration rice varieties (especially *ADT 36*), the highest grain yields were obtained from 66 to 100 hills m^{-2} depending on the soil type and soil fertility. For the short duration varieties (ADT 36 and ADT 43) during *Rabi* season 66 to 80 hills m^{-2} were found to give higher grain yield than the other plant densities under Tamil Nadu conditions.

For medium duration rice varieties there was much variation among the varieties in respect of plant density requirement to obtain higher yield. For example, the variety *R 711* was found to give on par yield at 33, 44 and 66 hills m^{-2} at Maharastra. The variety *Kranti* registered the highest grain yield at a plant density from 66 to 100 hills m^{-2} depending on the soil type and soil fertility in Chattisgarh state. In Tamil Nadu, 80 hills m^{-2} was found to give the highest grain yield in respect of rice varieties *ADT 36*, *ASD19* and *ADT 39*.

Similar trend was observed for most of the medium duration rice varieties during *Rabi* season also. For example, varieties such as *ADT 36*, *CO 45* and *IR 20* were found to give comparable yield at 33 and 50 hills m^{-2}. However, *ADT 38*, *ASD 19*, *ADT 39* and *CO 43* were found to give the highest grain yield at 80 hills m^{-2}.

During *Kharif* season, in long duration rice variety such as *CR 1018*, the yield was comparable at 33 and 44 hills m^{-2} at Cuttack. Similarly long duration varieties such as *Intan* and *DWR 4107* were found to give comparable yields at 30, 35, 40, 45 and 50 hills m^{-2} at Mudigere (Karnataka) and the long duration rice variety *Norin*

18 gave the highest yield at 50 hills m^{-2} at Imphal. This suggested that long duration varieties might give higher yield from the plant densities ranging from 33 to 50 hills m^{-2} under different soil types and agroclimatic conditions.

For *Basmati* type fine grain rice varieties, depending on the duration and soil type 44 to 66 hills m^{-2} were found to give higher grain yield at different soil type and agroclimatic regions.

The medium duration rice hybrids were also found to differ in their plant density requirement for higher yield. For example, the hybrid *APHR 2* gave the highest grain yield at 44 hills m^{-2} during *Kharif* season at Andhra Pradesh. Whereas, similar rice hybrid of medium duration (*CORH* 2) was found to give the highest yield at 50 hills m^{-2} in Tamil Nadu during *Rabi* season. At Chattisgarh, the rice hybrid *6201* gave the highest yield at 66 hills m^{-2} during *Kharif* season.

All these literatures indicated in general that higher plant density gave higher grain yield irrespective of soil type, geographical location and season. However, the rice varieties or hybrids were found to differ in their optimum plant density, since their adaptation is highly location specific.

2.3. Nitrogen levels and crop response

The yield response of rice to fertilizer application is an aggregate of various factors such as variety, duration, soil type, irrigation facilities, insect pest problems, rain fall distribution, humidity, sunshine hours, etc. The yield response to other nutrients is much less predictable than its response to nitrogen. Unless a soil lacks phosphorus or potassium there will be no response or much lower response to phosphorus or potassium as compared to nitrogen. Many scientists have observed positive response to applied nitrogen in rice (Khatua *et al.*, 1976, Sharma and Mitra, 1990, Bhattacharya and Singh, 1992, Mahajan and Tripathi, 1992, and Kurmi *et al.*, 1993).

Nitrogen is the key nutrient element limiting the yield of rice. Fertilizer N use efficiency varies from 18 to 40 per cent in rice soils because applied inorganic N is rapidly lost from the soil-flood water system by ammonia volatilization and denitrification (Natarajan and Phushpavalli, 1994). Though nitrogen is a major nutrient for higher productivity in rice, its efficiency never exceeded 40 per cent under wetland conditions (Pandey and Tripathi, 1994). Nitrogen use efficiency was known to vary with the age of seedlings planted (Singh *et al.*, 1999).

2.3.1. Plant growth

Leaves are the primary sites for both carbon fixation (photosynthesis) and synthesis of nitrogenous compounds. Nitrogen concentration in the leaves is reported to be linearly related to net assimilation rate (Keulen and Seligman, 1987). Similarly net assimilation rate was linearly related with dry matter production (Murthy *et al.*, 1986 and Drenth *et al.*, 1994).

When single basal and equal split application of N at 30,60,90,120 and 150 kg N ha^{-1} were compared in a sandy clay loam soil at Faisalabad (Pakistan) in *Basmati 370* rice variety, the number of tillers $hill^{-1}$ was found to increase with each increment of N fertilizer and were higher with single N application than split application (Hussain *et al.*, 1989).

At Allahabad (Uttar Pradesh), rice varieties *Ratna* (dwarf) and *Saket 1* (tall) gave increased tillering and dry matter production at later growth stages at higher dose of N (100 kg N ha^{-1}) as compared to lower dose of 80 kg N ha^{-1} during wet (*Kharif*) season (Agasimani *et al.*, 1983).

Nitrogen application was found to enhance the photosynthetic activity and total dry matter production. However, the effect was not always conspicuous and sometimes even deleterious with the increase in doses of N as it results in excessive vegetative growth and poor light interception. Studies at Tsukubashi in Japan with *indica* rice variety *Takanari* under two levels of nitrogen (50 and 100 kg N ha^{-1}) in wet season revealed that the leaf area index was maximum at 100 kg N ha^{-1} but the total dry weight at maturity was higher at 50 kg N ha^{-1} (Sarkar *et al.*, 1997).

Initial biomass partitioning was on leaves, later in the stems during panicle initiation stage and ultimately on the storage organs. The incremental biomass partitioning to leaf decreased after active tillering stage but it increased in stem and reached a maximum at panicle initiation stage and thereafter, there was a decrease as observed during dry season at Cuttak (Orissa) in a sandy clay loam soil when two rice varieties (*IR 36* and *Swarnaprabha*) of medium duration (125 -130 days) were evaluated under five levels of N (30,60,90,120 and 150 kg N ha^{-1}). Also at all levels of N, the stem fraction was maximum around panicle initiation stage. With the progress in plant growth, relatively more accumulates were used for the production of culm plus sheath and at anthesis, the dry matter of culm plus sheath was almost doubled to that of leaf weight. However, with increase in the N level, higher potential of new incremental biomass production was invested on leaves rather than on stems (Krishnan *et al.*, 1998).

Nitrogen fertilization and suitable genotype are the important factors for higher productivity of rice (Bali *et al.*, 1995). At Raipur, the plant height and effective tillers were increased positively by higher fertilizer dose of 120:60:40 kg NPK ha^{-1} as compared to 80:50:30 kg NPK ha^{-1} in four medium duration rice varieties (*Mahamaya*, *Kranti*, *R-296-260* and *Suraksha*) at both spacings *viz.*, 20x10 cm and 10x10 cm corresponding to 50 and 100 hills m^{-2} (Siddiqui *et al.*, 1999). Similarly the plant height of *Pusa Basmati 1* was increased by N upto 120 kg ha^{-1} during *Kharif* season at Karnal (Haryana), irrespective of plant density/ plant spacing *viz.*, 15x15, 20x15 and 30x15 cm corresponding to 44, 33 and 22 hills m^{-2} (Chopra and Chopra, 2000). Taller plants with greater LAI and DMP were obtained in a medium duration rice variety (*ADT 39*) during *Rabi* season at Karaikal (Union Territory of Pondicherry) upto 150 kg N ha^{-1} in a sandy clay loam soil (Rammohan *et al.*, 2000).

At Nigeria in a sandy loam soil, application of N fertilizer influenced the growth characters of rice such as plant height, CGR and RGR significantly upto 80 kg N ha^{-1}during rainy season in rice variety ITA 212. Nitrogen was found to influence photosynthetic rate of rice plant through development of leaf area and increase in photosynthetic rate per unit area, which ultimately led to increase in grain yield. The fact that most of the growth characters did not respond to fertilizer level beyond 80 and upto 120 kg N ha^{-1} rate was ascribed to the genetic limitation of the variety of rice used in the study (Lawal and Lawal, 2002).

2.3.2. Yield attributes and yield under different soil types

2.3.2.1.Clay soil

In a field experiment during rainy season (*Kharif*) at Raipur with medium duration rice variety *Kranti* under two levels of nitrogen (120 and 160 kg ha^{-1}), it was observed that the effect of increased level of fertilizer N was more pronounced and increased the grain yield substantially at 20x10 and 15x10 cm (50 and 66 hills m^{-2}) spacings (Pandey and Tripathi, 1993). Evaluation of scented rice varieties (*HKR 228*, *Pusa 615*, *RP 2144* and *Basmati 370*) under five levels of N (0,30,60,90 and 120 kg ha^{-1}) during wet season at Hyderabad, revealed that nitrogen application influenced grain yield, panicle weight and panicle number significantly. Incremental doses of nitrogen increased the mean grain yield significantly upto 90 kg N ha^{-1} beyond which there was no further significant increase in the grain yield (Singh and Pillai, 1996).

Increase in fertilizer N levels (100,125 and 150 kg N ha^{-1}) was found to improve the grain yield of aged seedlings (25, 35 and 45 days) of rice variety *IR 64*. Nitrogen at 150 kg ha^{-1} had significantly higher number of panicles and grain $panicle^{-1}$ and resulted in higher grain yield than at lower doses of N during rainy season at Gangawati, Karnataka (Channabasappa *et al.*, 1998). Similarly, field experiments conducted during wet seasons at Raipur with two scented rice varieties (*Pusa Basmati 1* and *Madhuri 11*) under 3 levels of N (40,80 and 120 kg ha^{-1}) revealed that the application of N at 80 and 120 kg ha^{-1} were at par and produced significantly high head rice recovery both at 20x10 and 15x10 cm (50 and 66 hills m^{-2}) spacings (Pandey *et al.*, 1999).

2.3.2.2.Laterite soil

Evaluation of long duration rice variety (*IET 7191*) under three levels of nitrogen (50,75 and 100 kg ha^{-1}) revealed that significantly higher grain yields were obtained with the application of 75 kg N ha^{-1} and it was on par with 100 kg N ha^{-1} under rainfed condition in *Kharif* (Mutanal *et al.*, 1997).

2.3.2.3.Saline soil

A field experiment conducted at Iksan (Korea) in a reclaimed saline soil under four levels of nitrogen (100,150,180 and 210 kg ha^{-1}) revealed that seedling establishment increased slightly upto 180 kg N ha^{-1} but decreased at 210 kg N ha^{-1}. Panicle number and spikelet number per unit area increased significantly at 180 kg

N ha^{-1} and the fertilizer level of 180 kg N ha^{-1} was found to prevent field lodging of rice (Lee *et al.*, 1998).

2.3.2.4.Silty loam soil

It was observed in a field experiment at Pusa (Bihar) during wet season in rice variety *Sujatha* with four levels of nitrogen (0,50,100 and 150 kg ha^{-1}) that rice grain and straw yields increased significantly with N upto 100 kg ha^{-1}. Additional N was found to increase yields marginally. However, when Zn accompanied N, a significant increase in grain yield was registered upto 150 kg N ha^{-1} during wet season (Singh *et al.*, 1995).

In a field study at Faizabad (Uttar Pradesh) during the rainy season (*Kharif*) with rice variety *Sarjoo 52* under three levels of N (40,80 and 120 kg ha^{-1}), it was observed that application of 120 kg N ha^{-1} improved significantly all yield attributes and yield over its lower levels (Singh and Singh, 1998).

2.3.2.5.Silty clay loam soil

Field experiment at Srinagar (Kashmir) during wet season (*Kharif*) with rice variety *K 39* under three nitrogen levels (40,80 and 120 kg ha^{-1}) revealed that upto 80 kg N ha^{-1} there was significant increase in grain yield with concomitant improvement in all yield attributes (Hasan *et al.*, 1996).

Studies at Raipur during *Kharif* season in direct sown six early duration rice varieties (*TRC 80-291*, *NDR 1021*, *Vandana*, *RR 180-1*, *Poornima* and *Annada*) with five nitrogen levels (0,40,80,120 and 160 kg ha^{-1}) revealed that the application of nitrogen upto 120 kg ha^{-1} significantly increased grain yield, panicle m^{-2} and grain $panicle^{-1}$. The test weight was also increased with increasing N levels upto 80 kg ha^{-1}. This indicated that nitrogen application increased N supplies to plant, increased the N concentration and uptake. Also it was found that the nitrogen use efficiency decreased with increased levels of N (Pandey *et al.*, 2000).

2.3.2.6.Sandy clay loam soil

At Madurai (Tamil Nadu), testing of rice hybrid (*CORH 2*) under three nitrogen levels (150, 200 and 250 kg ha^{-1}) during *Rabi* season revealed that there was no appreciable change in the yield attributes due to application of higher dose of N above 150 kg ha^{-1}, irrespective of plant density (25, 33 and 50 hills m^{-2}). The yield attributes *viz*., panicles m^{-2}, panicle weight, panicle length and grains $panicle^{-1}$ did not vary much at 200 and 150 kg N ha^{-1}. An appreciable reduction was noticed in important yield attributes like panicles m^{-2}, filled grains $panicle^{-1}$ at 250 kg N ha^{-1}. This was ascribed to vegetative growth at higher dose of N application, resulting in declining trend in yield attributes. The straw yield increased at 250 kg N ha^{-1} than at 150 and 200 kg N ha^{-1}. Application of higher dose of N promoted more biomass, resulting in significant increase in straw yield. With respect to B: C ratio, application of 150 kg N ha^{-1} was found more remunerative than other levels of N (Rajarathinam and Balasubramaniyan, 1999).

Screening of three rice varieties (*Kavya*-135 days, *Pothana*-125 days and *WGL 18011-105* -110 days) during *Kharif* season and two varieties (IR 64 -125 days and *Kalinga III* - 90 days) during *Rabi* season under four levels of N (0,40,80, and 120kg ha^{-1}) at Jagitial (Andhra Pradesh) in direct seeded condition revealed that under late seeded conditions, there was significant increase in grain yield upto 120 kg N ha^{-1} in the first year (*Rabi* season) only. However, the grain yield increased significantly upto 80 kg N ha^{-1} during *Kharif* season in the first year and *Rabi* season in the second year. The yield difference between 80 and 120 kg N ha^{-1} was not significant during these seasons in this experiment (Reddy and Kumar, 1999).

Field experiment conducted during *Rabi* at Karaikal (U.T. of Pondicherry) with medium duration rice variety ADT 39, at four levels of nitrogen (0,75,112.5 and 150 kg ha^{-1}) revealed that the number of productive tillers $hill^{-1}$ increased linearly with increase in N level and application of 150 kg N ha^{-1} resulted in the highest number of productive tillers. The grain and straw yields were also higher at 150 kg N ha^{-1} than at other N levels (Rammohan *et al*., 2000).

2.3.2.7.Clay loam soil

In an investigation at Sriniketan (West Bengal) during wet season with short duration rice variety *IR 50* under three levels of N (60,100 and 140 kg ha^{-1}), it was observed that the crop responded upto 100 kg N ha^{-1} with increase in yield and effective tillers. Further increase in N upto 140 kg ha^{-1} reduced the filled grains $panicle^{-1}$ and test weight since the crop was infested by blast and lodged owing to luxuriant foliage growth (De and Chowdhury, 1995).

The rice variety *Rasi* when evaluated under five levels of N (0,40,80,120 and 160 kg ha^{-1}) with two sources of N (prilled and large granular urea) and with 30, 45 and 60 days old seedlings during dry season revealed that application of nitrogen was found to increase the grain yield significantly upto 120 kg ha^{-1} and the optimum dose was worked out to be 112 kg of N ha^{-1} as prilled urea in three split applications at Hyderabad (Singh *et al.*, 1996).

During *Rabi* season, an evaluation of six long duration rice varieties (*IET 5914*, *IET9670*, *IET 8002*, *CR 1009*, *AD 86465* and *Pankaj*) under five levels of N (0,40,80,120 and 160 kg ha^{-1}) at Aduthurai (Tamil Nadu) revealed that maximum grain yield was recorded with 160 kg N ha^{-1} in the first year. Accumulation of non-structural carbohydrate and stored nitrogenous compounds were the basis for increased harvest index and grain yield in long duration cultivars. During the second year, the grain yield was maximum under 160 kg N ha^{-1} but it was on par with 120 and 80 kg N ha^{-1} (Muthukrishnan *et al.*, 1997). This indicated wide variation in the response of rice varieties from 80 to 160 kg N ha^{-1}, even within same season. It was attributed to variation in weather parameters as well as the native soil fertility.

Progressive and significant yield increases were observed in *Andrewsali* rice varieties irrespective of seedling age (35, 45, 55 and 65 days) with increase in N level from 0 to 60 kg ha^{-1} at Assam during *Rabi* season. Similar trend was also observed in straw yield. Panicle number m^{-2} increased progressively with increase in N level. An increasing trend of grains $panicle^{-1}$ in accordance with N application was observed. N levels did not seem to influence test weight of grains (Choudhary *et al.*, 1997). In another field experiment conducted during *Rabi* season at Karimganj (Assam) with *Andrewsali* rice variety with 35 days old seedlings under four levels of nitrogen (0,20,40 and 60 kg ha^{-1}), it was observed that the yield response to increasing rates of N was almost linear and significant. The increase in yield at higher levels of N was attributed to superior yield attributes like panicles m^{-2}, filled grains $panicle^{-1}$ and 1000 grain weight. At higher N levels, P and K conspicuously improved the yields (Sarmah, 1998). Studies with 60 days old aged seedlings of short duration rice variety (*ADT 36*) with 0, 100 and 125 kg N ha^{-1} revealed that nitrogen application at 100 kg ha^{-1} enhanced the productive tillers, filled grains $panicle^{-1}$ as compared to no nitrogen application. Further increase in N (125kg ha^{-1}) also enhanced the productive tillers, filled grains $panicle^{-1}$ and finally the grain yield when the crop was raised during December-March, irrespective of plant population *viz.*, 50, 66 and 80 hills m^{-2} (Ramasamy and Babu, 1997).

During *Kharif* season the high yielding medium duration varieties (*Mahamaya, Kranti, R-296-260* and *Suraksha*) were found to respond upto 120 kg N ha^{-1} and produced significantly higher grain yield as compared to 80 kg N ha^{-1} at Raipur, indicating that varieties with high yield potential needs more quantity of nutrients to produce maximum grain yield (Siddiqui *et al.*, 1999).

At Ranchi (Bihar) during rainy season when four scented rice varieties (*Sugandha*, *Basmati 370*, *Pusa Basmati 1* and *BR10*) were evaluated under three levels of nitrogen (60,80 and 100 kg ha^{-1}), it was observed that each incremental dose of nitrogen gave significantly higher grain and straw yield, net return, benefit: cost ratio as well as physical and monetary productivity over its preceding dose. Consequently, the crop fertilized with 100 kg N ha^{-1} gave maximum grain yield (Singh *et al.*, 2000). On the contrary, in a field experiment at Karnal (Haryana) during rainy season (*Kharif*) with a scented rice variety (*Pusa Basmati-1*) at four levels of nitrogen (0,40,80,and 120 kg ha^{-1}), it was inferred that application of N at the rate of 80 or 120 kg ha^{-1} improved all the yield attributing characters over the control. Incremental doses of N were found to increase the number of panicles $plant^{-1}$. Maximum panicles $plant^{-1}$ was recorded at 120 kg N ha^{-1}. Seed weight $panicle^{-1}$ increased significantly upto 80 kg N ha^{-1}, irrespective of plant spacing (15x15, 20x15 and 30x15 cm with 44, 33 and 22 hills m^{-2}) and declined at the highest dose. Panicle length and 1000 grain weight remained unaffected due to N. Nitrogen had marked effect on seed yield. Seed yield increased significantly with increase in N upto 80 kg ha^{-1}, which was attributed to high dry matter production and its translocation to the sink. Increase in the number of panicles $plant^{-1}$ and seed weight $panicle^{-1}$ was mainly responsible for the increased yield at this level of N. The straw yield also significantly increased with increasing level of N. Vigorous growth with increase in N level resulted in higher straw yield (Chopra and Chopra, 2000).

2.3.2.8.Sandy loam soils

In a field experiment at Bhubaneswar with *IR 36* rice variety at four levels of N (0,30,60 and 90 kg ha^{-1}), it was observed that nitrogen application significantly increased grain yield. Yield increased with each incremental increase in N (Patra and Padhi, 1989). The results from an another experiment at Bhubaneswar during wet seasons with rice variety *Daya* under four levels of nitrogen (0,40,80 and 120 kg ha^{-1}) revealed that nitrogen had a marked effect on yield. Grain yield increased significantly with an increase in level of nitrogen upto 80 kg ha^{-1} during the first year and upto 120 kg ha^{-1} during the second year. During both the years, straw yield increased upto 120 kg N ha^{-1}. The higher yield at higher level of N was attributed to high N uptake leading to high dry matter production and its translocation to the sink (Panda *et al.*, 1995).

Studies at Semiliguda (Orissa) during the wet season with two very short duration rice varieties (*Heera* - 83 days and *Kalyani II* - 79 days) under direct sowing with three levels of nitrogen (20,40 and 60 kg ha^{-1}) revealed that maximum grain yield was obtained at 60 kg N ha^{-1} due to more panicles m^{-2} and grains $panicle^{-1}$ (Mohapatra *et al.*, 1997). At Nigeria, during wet season, the number of ear bearing tillers, per cent filled grains, grain: straw ratio, 1000 grain weight and yield were found to increase significantly with N rates upto 80 kg ha^{-1} in rice variety *ITA 212*. Most of the growth factors did not respond to fertilizer N beyond 120 kg ha^{-1} due to genetic limitation of the variety of rice used in the study (Lawal and Lawal, 2002).

From the foregoing literature it is summarised that the rice varieties were found to respond from 60 to 160 kg N ha^{-1} depending upon the method of sowing/ planting, planting density, soil type and soil fertility, season of planting (climate), age of seedling and crop duration. Very short duration rice varieties like *Heera* and *Kalyani II* under direct sown condition with 66 hills m^{-2} as plant density were found to respond only upto 60 kg N ha^{-1} during *Kharif* season in Orissa. Similarly the rice variety *Andrewsali* was found to respond upto 60 kg N ha^{-1} in Assam even if 35, 45, 55 and 65 days old seedlings were planted irrespective of plant density. Most of the *Basmati* type rice varieties were found to respond upto 80-100 kg N ha^{-1} irrespective of soil type, season and plant density. The hybrid rice genotypes were found to respond from 100 to 150 kg N ha^{-1}. A medium duration rice hybrid (*CORH 2*) in Tamil Nadu gave the highest yield at 150 kg N ha^{-1} during *Rabi* season. Similarly the short duration rice hybrid (*ADTRH 1*) was found to give the highest yield at 150 kg N ha^{-1} in Tamil Nadu during *Kharif* season. Another medium duration rice hybrid (*APHR 2*) at Andhra Pradesh gave the highest yield at 120 kg N ha^{-1}. The hybrid *6201* was able to produce the highest yield even at 100 kg N ha^{-1} at Chattisgarh state.

The short duration rice varieties were found to respond from 80 to 150 kg N ha^{-1} (*IR 64*) during *Kharif* season, according to soil type and fertility and plant density. Whereas, some short duration varieties were found to respond from 80 to 125 kg N ha^{-1} (*ADT 36*) during *Rabi* season depending upon the soil type and plant density. Most of the medium duration rice varieties were found to respond from 80 to 160 kg N ha^{-1} (*Kranti*) during *Kharif* season while the response was from 80 to 150 kg N ha^{-1} (*ADT 39*) during *Rabi* season. This indicated that irrespective of the season and soil type, medium duration rice varieties were found to respond almost in a similar fashion (80 to 150/160 kg N ha^{-1}). The response of long duration rice varieties to nitrogen was very less as compared to short and medium duration rice varieties. For example, in a laterite soil the long duration rice variety *IET 7191* with a plant density of 50 hills m^{-2} gave the highest yield at 75 kg N ha^{-1} and it was on par with that of 100 kg N ha^{-1} during *Kharif* season at Karnataka. Similarly six long duration rice varieties (*IET 5914*, *IET 9670*,*IET 8002*, *CR 1009*, *AD 86465* and *Pankaj*) were found to respond upto 80 kg N ha^{-1} in a clay loam soil during *Rabi* season and their yields were on par at 80, 120 and 160 kg N ha^{-1}.

Addition of zinc was found to enhance the response of rice varieties to applied nitrogen probably when there was zinc deficiency. For instance, the rice variety *Sujatha* was found to respond upto 100 kg N ha^{-1} without zinc. When zinc was also added the response went upto 150 kg N ha^{-1} during *Kharif* season in a silty loam soil at Pusa (Bihar).

2.3.3. Nitrogen levels, water regime and yield

There is need for continuous submergence at higher N application levels for a good crop response to fertilizer. Lack of submergence during reproductive stage was found to reduce the yield benefits under higher N application during *Rabi* season at Raipur (Jaggi *et al.*, 1985).

In a glass house study with a pot culture experiment at Palampur (Himachal Pradesh), the highest grain yield of rice was obtained under continuously submerged condition at each level from 50 to 150 kg N ha^{-1} when N was applied at 0, 50, 100, 150 and 200 kg ha^{-1}. The water deficit generally decreased the grain yield. Under continuous submergence, the grain yield increased progressively with the increasing levels of N application. Moisture stress significantly affected the grain yield. Nitrogen and moisture interaction affected the grain yield more than the straw yield. Increased spikelet sterility was partly responsible for the reduction in grain/straw ratio at higher N levels and under moisture stress conditions. Application of N upto 100 -150 kg N ha^{-1} increased the grain yield of rice under water deficit conditions if the moisture stress occurred after the anthesis or was of lower magnitude during the vegetative phase (Sharma *et al.*, 1997).

2.3.4. Nitrogen levels and pests and disease incidence

Field investigation on the incidence of leaf folder pyralid (*Cnaphalocrocis medinalis*) on two susceptible varieties (*IR 20* and *CO 43*) and one moderately resistant variety (*IET 5741*) at two levels of nitrogen (120 and 180 kg ha^{-1}) and two plant spacings (20x10 and 20x15 cm with 50 and 33 hills m^{-2}) during *Kharif* and *Rabi* seasons in Tamil Nadu revealed that the higher dose of N recorded significantly higher infestation than the lower dose at *Kharif*, but there was no significant difference in infestation between the two nitrogen levels at *Rabi* (Rajendran, 1985). When three upland rice varieties (*Faro 11*, *E 425* and *R 66*) were evaluated on sandy loam soil at Ibadan (Nigeria) under three levels of nitrogen (0,30, and 60 kg ha^{-1}), the crops experienced more stem borer damage and high lodging percentage at 60 kg N ha^{-1} than at other levels of nitrogen (Kehinde and Fagade, 1987).

Studies on effect of nitrogen levels on false smut caused by *Usitilagoinoidea virens* in rainfed rice *Himalaya 741* at Malan (Himachal Pradesh) under three levels of N (25, 40 and 80 kg ha^{-1}) revealed that higher levels of N in split doses resulted in higher number of smutted florets m^{-2} (Bhardwaj *et al.*, 1989). When scented rice cultivars *Basmati 370*, *Pakistan Basmati 7412*, *IET 8580*, *IET 8579* and *Badshabhog* were grown under four N levels (0,30,60 and 90 Kg ha^{-1}) during wet season in Cuttack (Orissa), it was observed that at higher levels of N, bacterial leaf blight and bacterial blight disease severity increased between 35 and 45 days after transplanting with a steep decline thereafter which was ascribed to abundant availability of N initially coupled with favourable weather conditions and were milder at lower N doses (Reddy *et al.*, 1989).

The investigations carried out an Kalyani (West Bengal) in an entisol using rice cultivar *CR 222 MW 10* with four fertilizer levels (control, N_{80}, $N_{80}P_{40}$ and N_{80} P_{40} K_{40} kg ha^{-1}) had revealed that fertilizer application did not show any pronounced effect on green leaf hopper population at different growth stages but when N fertilizer was balanced with both P and K fertilizers, the decrease in pest population was more than those receiving N alone or N and P in combination. At early tillering stage, fertilizer treatments influenced stem borer incidence significantly. Nitrogen along with P increased the stem borer infestation over control. But when N and P were balanced with K fertilizer, there was decreasing trend of damage over N and P treatment. Nitrogen alone increased the gall midge incidence but when combined with P and K, there was reduction in gall midge incidence. Fertilizer treatments did not show any significant effect on rice leaf folder and rice bug incidence except for later stages of crop growth for rice bug. Different fertilizer combinations significantly increased the disease incidence at mid and late tillering stages but not at early tillering stage. Fertilizer application increased the incidence of bacterial leaf streak disease over the control. This increase mainly was due to N fertilization (Pramanick *et al.*, 1995).

An increase in population of brown plant hopper and white backed plant hopper in rice varieties was reported due to high doses of nitrogen. Results from a field trial with two rice varieties (*ADT 38* and *ADT 40*) during *Rabi* season with four levels of nitrogen (0,100,125 and 150 kg ha^{-1}) at Aduthurai revealed that 100 kg N

ha^{-1} recorded less green leafhopper than the higher doses of nitrogen. The green leafhopper population increased with increasing levels of N (Raju *et al.*, 1998).

From the above literature cited, it is inferred that nitrogen levels highly influenced the pest and disease load of rice crop but the influence depends on variety, soil type, season, climate and plant population level etc.

2.4. Nitrogen levels, age of seedlings and plant density

2.4.1. Nitrogen levels and age of seedlings

In field trials at Kapurthala (Punjab) during wet season with five levels of nitrogen (0,60,90,120 and 150 kg N ha^{-1}), three ages of seedlings (30,45 and 60 days) and three dates of planting (30 June, 20 July and 9 August), it was observed that transplanting of 60 days old seedlings out yielded 30 and 45 days old seedlings with much higher differences under unfertilized control (0.58–1.1 t ha^{-1}) and with fairly higher differences at all the N levels (0.18–0.48 t ha^{-1}). Late transplanted 60 days old seedlings had much higher N recovery than 30 and 45 days old seedlings. The increase in grain yield and N recovery with older seedlings was the net result of balanced dry matter production, early flowering and high spikelet fertility. Early planting (30^{th} June) gave the highest yield and the yield declined thereafter and the lowest yield was recorded in the late planting (9^{th} August), irrespective of age of seedlings. However, the yield difference between 30, 45 and 60 days old seedling was not significant in early planting, while there was little difference in yield due to different aged seedlings in July planting and the yield difference was significant between the seedlings of different age due to late planting in August. Even when planting was delayed (August), the highest grain yield was recorded with 60 days old seedlings, followed by 45 days old seedlings and the lowest yield obtained in 30 days old seedlings. Even with higher N levels the grain yield declined, irrespective of seedling age due to delayed planting (9^{th} August) as compared to early planting (30^{th} June). These results indicated that early planting with higher levels of N (150 kg ha^{-1}) gave the highest yield even with aged seedlings of 60 days old (Gill and Shahi, 1986).

At Dapoli, in a clay loam soil the rice variety *R 711* (120 days duration) was evaluated at three seedling ages (25, 35 and 45 days), three levels of nitrogen (75,100 and 125 kg ha^{-1}) and three plant spacings (15x10, 15x15 and 20x15 cm with 66, 44 and 33 hills m^{-2}) in wet season. The results revealed that transplanting of 25 days old seedlings with higher level of nitrogen (125 kg ha^{-1}) produced the highest grain yield at 15x10 cm spacing (66 hills m^{-2}). However, it was on par with the yield obtained by transplanting of 35 and 45 days old seedlings with the same level of nitrogen. Yields from 25 and 35 days old seedling with 100 kg N ha^{-1} were on par with that of 25 days old seedlings at 75 kg N ha^{-1} (Wagh *et al.*, 1988). Field trials conducted during dry season (winter) at Hyderabad in a clay loam soil with short duration rice variety *Rasi* (115 days) under five levels of nitrogen (0,40,80,120 and 160 kg ha^{-1}) as prilled and large granular urea with three ages of seedlings (30,45 and 60 days) revealed that 30 and 45 days old seedlings produced the maximum and comparable grain yield at 120 kg N ha^{-1} than 60 days old seedlings. The large granular urea gave significantly higher grain yield than prilled urea (Singh *et al.*, 1996).

Studies at Coimbatore in a clay loam soil with 60 days old aged rice seedlings of short duration rice variety *ADT 36* under three levels of nitrogen (0, 75, 100 and 125 kg ha^{-1}) at different plant densities (50, 66 and 80 hills m^{-2}) revealed that nitrogen application at 125 kg ha^{-1} (25 per cent extra N at basal) enhanced productive tillers, filled grains $panicle^{-1}$ and finally the grain yield. Use of one or two seedlings $hill^{-1}$ gave higher yield than that of bunch planting using six to eight seedlings $hill^{-1}$ (Ramasamy and Babu, 1997).

An investigation carried out at Gangavati (Karnataka) in a black clayey soil using a short duration rice variety (*IR 64*) with three ages of seedlings (25,35 and 45 days) under three nitrogen levels (100,125 and 150 kg ha^{-1}) during rainy (*Kharif*) season, it was observed that at 150 kg N ha^{-1}, 35 and 45 days old seedlings were found to give on par yield. Use of two to three seedlings $hill^{-1}$ gave higher grain yield than the use of four to five and six to seven seedlings $hill^{-1}$, irrespective of age of seedlings (Channabasappa *et al.*, 1998).

A field experiment conducted at Faizabad (Uttar Pradesh) in a silty loam soil using rice variety *Sarjoo 52* with three ages of seedlings (25, 35 and 45 days) under three levels of nitrogen (40,80 and 120 kg ha^{-1}) revealed that 25 days old seedlings with 120 kg N ha^{-1} in three splits gave maximum yield and monetary advantage over other combinations during *Kharif* season (Singh and Singh, 1998).

2.4.2. Nitrogen levels and planting density

In field experiments at Chiplima (Orissa) in a sandy clay loam soil with rice variety *Jaya* under four levels of nitrogen (0,50,100 and 150 kg ha^{-1}) and two spacings (15x10 cm and 30x10 cm with 66 and 33 hills m^{-2}), it was found that the grain yield increased significantly, with increasing level of nitrogen upto 150 kg N ha^{-1}, irrespective of spacing. The grain yield of rice was not affected significantly by spacing or plant density and planting directions *viz.*, north – south and east - west (Gulati *et al.*, 1987). In Islamabad (Pakistan), studies with rice variety *IR 6* under four plant densities (10,16,20 and 25 hills m^{-2}) and four levels of nitrogen (0,60,90, and 120 kg ha^{-1}) revealed that the highest plant density of 25 hills m^{-2} with 120 kg N ha^{-1} gave the highest grain yield. The fertilizer use efficiency was the lowest at the highest level of fertilization and it was the highest at highest plant density (Zia, 1987).

No significant difference in grain yield was observed due to different plant densities (66,44 and 33 hills m^{-2}) and application of 125 kg N ha^{-1} produced higher grain yield than other levels of 75 and 100 kg N ha^{-1} at Dapoli in a clay loam soil with rice variety *R 711* of 120 days duration (Wagh *et al.*, 1988). In a field experiment at Raipur, in a clay soil with a medium duration rice variety *Kranti* under two levels of plant population (50 and 66 hills m^{-2}) and two levels of nitrogen (120 and 160kg ha^{-1}), it was observed that the crop planted at 33 per cent high density with closer spacing (66 hills m^{-2}) and fertilized heavily with 160 kg N ha^{-1} (33 per cent extra N) gave the maximum grain yield than recommended dose of 120 kg N ha^{-1} during *Kharif* season (Pandey and Tripathi, 1993). The yield advantage with higher plant density at higher level of N was further confirmed at Raipur in same soil type when four medium duration rice varieties (*Mahayama*, *Kranti*, *R-296-260* and *Suraksha*) were evaluated by Siddique *et al* (1999) during *Kharif* season.

At Madurai (Tamil Nadu) in a sandy clay loam soil, it was found that the rice hybrid *CORH 2* gave maximum grain yield at a high plant density of 50 hills m^{-2} at

200 kg N ha^{-1} as compared to other population (25 and 33 hills m^{-2}) and other N levels (150 and 250 kg ha^{-1}) during *Rabi* season (October – November to January – February). But the nitrogen use efficiency was more at 150 kg N ha^{-1} with 50 hills m^{-2} which resulted in higher economic yield in hybrid rice (Rajarathinam and Balasubramaniyan, 1999). Experiments in farmer's holdings in Irugur soil series (Typic Ustropepts having shallow to moderate depth) of Erode district (Tamil Nadu) with two population densities (66 and 80 hills m^{-2}) and three levels of nitrogen (fertilizer nitrogen for an yield targets of 6,7 and 8t ha^{-1}(278 kg N ha^{-1}) based on STCR recommendation) revealed that application of higher doses of N for an yield target of 8t ha^{-1} with the highest plant population of 80 hills m^{-2} recorded significantly higher grain and straw yields as well as N uptake both during *Kharif* and *Rabi* seasons (Santhi *et al.*, 2000).

At Coimbatore, experiments with rice variety *ASD 18* at three planting densities (33,66 and 100 hills m^{-2}) under SPAD meter guided N application revealed that wider spacing required lesser N as compared to closer spacing at a SPAD threshold value of 37. The grain yield was on par at 66 and 100 hills m^{-2} (6.2 t ha^{-1}). The grain yield per kg of N applied was 53.8 kg at 33 hills m^{-2}, 46.6 kg at 66 hills m^{-2} and 47.8 kg at 100 hills m^{-2} (Janaki *et al.*, 2000). Studies at Japan with an active tillering rice cultivar (*Nipponbare*) at four planting densities (11.1 to 44.4 hills m^{-2}) combined with four rates of nitrogen top dressing (0-7.5gm^{-2}) revealed that dense planting increased the number of differentiated and final spikelets and the effect of dense planting on spikelet number was more prominent as the rate of N applied at panicle initiation was increased (Kobayasi *et al.*, 2001).

2.4.3. Age of seedlings and planting density

In a field experiment at Aduthurai (Tamil Nadu) during dry season (*Kharif*) using 60 days old seedlings of *ADT 36* rice variety under three plant populations (80,66 and 50 hills m^{-2}), it was observed that higher plant density of 80 hills m^{-2} produced significantly higher grain yield mainly because of higher number of tillers unit area^{-1}, inspite of reduction in yield attributes (reduced number of tillers hill^{-1}, panicle weight and number of filled spikelets panicle^{-1}). (Increasing the number of seedlings (2,4,6 and 8 per hill) had an adverse effect on yield attributes and yield. Use of two seedlings hill^{-1} gave the highest grain yield (Ramasamy *et al.*, 1987).

The interaction studies between age of seedlings and plant population in clay loam soil with rice variety *R 711* (120 days duration) at Dapoli revealed that transplanting of the younger seedlings (25 days old) at higher plant density (66 hills m^{-2}) produced significantly higher grain yield than that of 35 and 45 days old seedlings at all plant densities (66,44 and 33 hills m^{-2}) when three seedlings hill^{-1} were used (Wagh *et al.*, 1988). Similar trend was observed at Warangal in a clay loam soil, wherein three ages of seedlings (30,45 and 60 days) and two plant densities (44 and 100 hills m^{-2}) were evaluated at three planting dates (30 July, 14 and 29 August). The results revealed that 30 days old seedlings at a plant density of 100 hills m^{-2} produced higher grain yield (Reddy and Reddy, 1991).

Planting of 35 days old hybrid rice seedlings (*APHR 2*) at a plant density of 44 hills m^{-2} produced higher yields at Hyderabad as compared to 25 and 45 days old seedlings at plant densities of 44 and 33 hills m^{-2} (Padmaja and Reddy, 1998). In a field experiment at Raipur, during *Kharif* season with medium duration rice variety *Kranti* under three ages of seedlings (30,40 and 50 days) and three plant densities (25,33 and 50 hills m^{-2}), it was observed that higher plant density (50 hills m^{-2}) with 30 days old seedlings produced higher grain yield than seedlings of other ages with lower plant density (Patel, 1999). Almost similar results were observed at Imphal (Manipur). Higher plant density of 50 hills m^{-2} with closer spacing of 20x10 cm was found to produce higher yield at all ages of seedlings (20,27,34, 41 and 48 days old) as compared to other lower plant densities (25 and 33 hills m^{-2}) in rice variety *Norin 18*. Among the seedlings, 27 days old seedlings were found to be beneficial from the yield point of view than other ages during the wet season (Devi and Singh, 2000).

From the above literature, it is inferred that for the late or delayed planting of the short and medium duration rice varieties, aged seedlings of 45-60 days could be used without much reduction in yield. But the plant density should be increased from 25 to 33 per cent over the recommended plant density, irrespective of the season and soil type. Under late planting situation, plant densities ranging from 66 to 100 hills m^{-2} are recommended taking into consideration the variations in rice genotypes, soil types and seasons. Two to three seedlings $hill^{-1}$ is recommended than bunch of seedlings $hill^{-1}$ (5-8 $hill^{-1}$) for delayed planting situation using aged seedlings to achieve more number of tillers per unit area. Similarly, the fertilizer nitrogen dose needed was found to vary from 125 to 150 kg N ha^{-1} (25 to 33 % extra than recommended dose) for delayed planting of rice with aged seedlings, irrespective of rice genotypes, soil types and seasons. The medium duration rice hybrids (*APHR 2* and *CORH 2*) were found to require 44 - 50 hills m^{-2} with 150 – 200 kg N ha^{-1} when delayed planting is done with 35 days old seedlings.

From the above overall review, it could be understood that exists an interaction exists between age of seedlings, plant density and the nitrogen levels applied to the rice crop. However, such information on "Improved *White Ponni*", a popular rice variety in Karaikal region was not available. Since Karaikal region is encountering the problem of late receipt of canal water for the past one decade the farmers were forced to plant aged rice seedlings in main field which affects the rice yield drastically. Among the various rice varieties grown at Karaikal, there is good marketability and premium price in the market for *I.W.Ponni* rice variety. Hence, farmers are raising *I.W.Ponni* rice variety in more area in Karaikal region. This rice variety seems to be a low fertilizer responsive since it was found to lodge at 150-50-50 kg NPK ha^{-1} (the current blanket recommendation in Tamil Nadu and the same is followed in Karaikal region so far). Since there was no research on the management of aged seedlings of *I.W.Ponni* rice variety with reference to fertilizer N and plant density, the present investigation was taken up in 2001-2002 during late *Samba* and late *Thaladi* seasons both coinciding with *Rabi* season, with four ages of seedlings (25, 32, 39 and 46 days old), two levels of plant population (50 and 66 hills m^{-2}) and two levels of nitrogen doses (recommended level of 100 per cent N and 75 per cent of recommended dose of N).

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

An investigation on the "Agronomic management of aged seedlings of Improved *White Ponni* rice variety" was carried out through two field experiments. The materials and methods adopted for the experiments are described in this chapter.

3.1. Location

Two field experiments were laid out during *Rabi* season (2001-2002) in the field number A_8 of the Eastern Block of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal which is situated at an altitude of 4m from mean sea level between 10°49' and 11°01' N latitude and 78°43' and 79°52' E longitude. The field was relatively flat with a uniform slope.

3.2. Climate and weather

Karaikal enjoys tropical climate and receives an annual average rainfall of 1437.17 mm in 56 rainy days. The beneficial monsoon is North East monsoon, which accounts for 75.04 per cent of total rainfall during October to December. The South West monsoon contributes 16.58 per cent rain during June to September. Winter rains accounts for 2.79 per cent during January to February and summer rains (March to May) gives 5.58 per cent of total rainfall. Karaikal region comes under eleventh Agro climatic Zone of India and it is classified as PC2 – Coastal Deltaic Alluvial Plain Zone. The weather conditions that prevailed during experimental period of the year 2001 – 2002 are presented in Table 1 and 2.

3.3. Soil characteristics

The soil of the experimental field was sandy clay loam (*Fluventic Ustropept*). The fertility status of the soil was classified as low in available nitrogen (151 kg N ha^{-1}), medium in available phosphorus (16 kg P_2O_5 ha^{-1}) and medium in available potassium (158 kg K_2O ha^{-1}). Mechanical composition, physical and chemical properties of the soil are furnished in Table 3.

Table 1. Weather data during cropping season of experiment I (Late *Samba*)

Standard week	Period	Temperature (°C)		Relative Humidity (%)		Soil temperature °C (20 cm)	Wind Speed (kmph)	Sunshine Hours (hr)	Total Rainfall (mm)	Total ET (mm)	Dew fall (mm)
		Maximum	Minimum	7.12 hr	14.12 hr						
37	10-16th Sept. 2001	36.3	25.4	84	53	39.9	7.9	61.57	0.00	47.6	0.000
38	17-23rd Sept. 2001	36.3	26.0	85	51	37.9	8.5	38.63	0.00	41.3	0.000
39	24-30th Sept. 2001	33.6	24.6	86	61	33.6	8.6	17.70	59.00	34.3	0.000
40	1-7th Oct. 2001	34.2	25.0	80	68	33.1	8.1	32.54	50.25	36.7	0.000
41	8-14th Oct. 2001	33.6	25.1	88	65	34.7	6.7	47.97	9.50	32.9	0.094
42	15-21st Oct. 2001	32.6	24.9	90	66	34.0	6.7	39.80	64.50	27.2	0.393
43	22-28th Oct. 2001	30.9	23.9	92	80	30.3	6.5	19.40	168.25	18.0	0.330
44	29th Oct-4th Nov.2001	32.2	24.5	90	63	33.7	4.7	56.30	0.00	32.1	1.071
45	5-11th Nov. 2001	30.1	24.3	95	78	30.0	4.6	16.70	148.50	14.4	0.240
46	12-18th Nov. 2001	29.9	24.2	94	81	29.8	3.9	27.70	67.50	18.6	0.654
47	19-25th Nov. 2001	28.9	23.0	94	76	28.8	7.3	28.50	101.75	22.9	0.067
48	26th Nov-2nd Dec.2001	28.6	22.7	94	78	28.6	5.6	26.90	52.00	17.6	0.535
49	3-9th Dec. 2001	28.4	20.9	92	71	29.1	7.1	35.20	2.00	21.7	0.843
50	10-16th Dec. 2001	28.2	20.1	92	64	30.6	6.3	56.20	0.00	30.3	0.965
51	17-23rd Dec. 2001	27.5	22.7	90	85	27.4	10.3	16.40	169.50	17.8	0.000
52	24-31st Dec. 2001	27.4	22.3	94	79	27.3	8.0	14.70	354.50	13.9	0.240
1	1-7th Jan. 2002	28.0	21.5	94	73	27.8	8.4	37.10	5.25	22.3	0.770
2	8-14th Jan. 2002	28.0	21.0	94	68	29.1	8.2	48.70	41.00	25.6	0.887
3	15-21st Jan. 2002	28.2	20.2	94	65	30.6	5.3	51.20	0.25	27.5	1.050
4	22-28th Jan. 2002	30.2	21.9	96	68	31.9	4.0	37.30	0.00	23.8	1.870
5	29th Jan-4th Feb. 2002	28.7	22.0	94	78	28.9	9.0	25.30	229.50	19.4	0.522
6	5-11th Feb. 2002	28.5	21.2	94	71	28.1	5.5	45.10	40.00	22.7	0.974

Table 2. Weather data during cropping season of experiment II (Late *Thaladi*)

Standard week	Period	Temperature (°C)		Relative Humidity (%)		Soil temperature °C (20 cm)	Wind Speed (kmph)	Sunshine Hours (hr)	Total Rainfall (mm)	Total ET (mm)	Dew fall (mm)
		Maximum	Minimum	7.12 hr	14.12 hr						
43	22-28th Oct 2001	30.9	23.9	92	80	30.3	6.5	19.40	168.25	18.0	0.330
44	29th Oct-4th Nov. 2001	32.2	24.5	90	63	33.7	4.7	56.30	0.00	32.1	1.071
45	5-11th Nov. 2001	30.1	24.3	95	78	30.0	4.6	16.70	148.50	14.4	0.240
46	12-18th Nov. 2001	29.9	24.2	94	81	29.8	3.9	27.70	67.50	18.6	0.654
47	19-25th Nov. 2001	28.9	23.0	94	76	28.8	7.3	28.50	101.75	22.9	0.067
48	26th Nov-2nd Dec.2001	28.6	22.7	94	78	28.6	5.6	26.90	52.00	17.6	0.535
49	3-9th Dec. 2001	28.6	20.9	92	71	29.1	7.1	35.20	2.00	21.7	0.843
50	10-16th Dec. 2001	28.2	20.1	92	64	30.6	6.3	56.20	0.00	30.3	0.965
51	17-23rd Dec. 2001	27.5	22.7	96	85	27.4	10.3	16.40	169.50	17.8	0.000
52	24-31st Decrease 2001	27.4	22.3	94	79	27.3	8.0	14.70	354.50	13.9	0.240
1	1-7th Jan. 2002	28.0	21.5	94	73	27.8	8.4	37.10	5.25	22.3	0.770
2	8-14th Jan. 2002	28.0	21.0	94	68	29.1	8.2	48.70	41.00	25.6	0.887
3	15-21st Jan. 2002	28.2	20.2	94	65	30.6	5.3	51.20	0.25	27.5	1.050
4	22-28th Jan. 2002	30.2	21.9	96	68	31.9	4.0	37.30	0.00	23.8	1.870
5	29th Jan-4th Feb.2002	28.7	22.0	94	78	28.9	9.0	25.30	229.50	19.4	0.522
6	5-11th Feb. 2002	28.5	21.2	94	71	28.1	5.5	45.10	40.00	22.7	0.974
7	12-18th Feb. 2002	29.7	21.4	96	66	31.4	6.5	59.90	0.00	30.0	1.004
8	19-25th Feb. 2002	30.1	20.6	95	62	32.4	5.2	67.50	0.00	28.8	1.738
9	26th Feb-4th Mar.2002	30.9	20.9	97	60	33.6	5.0	65.90	0.00	33.4	1.874
10	5-11th Mar. 2002	31.7	21.4	92	62	34.7	5.1	53.10	0.00	31.4	1.344
11	12-18th Mar. 2002	32.0	22.3	92	57	35.6	5.5	54.50	0.00	33.9	0.819

Table 3. Characteristics of the experimental soil

Sl. No.	Contents	Contents
A	**Textural composition (Mechanical analysis)**	
1.	Clay (%)	26.00
2.	Silt (%)	3.76
3.	Fine sand (%)	64.98
4.	Course sand (%)	4.88
5.	Textural class	Sandy clay loam (*Fluventic Ustropept*)
B	**Chemical analysis**	
1.	Soil reaction (1:2) – pH	7.20
2.	Electrical conductivity (dSm^{-1})	0.29
3.	Organic carbon (%)	0.62
4.	Available nitrogen (kg ha^{-1})	151.00
5.	Available phosphorus (kg ha^{-1})	16.00
6.	Available potassium (kg ha^{-1})	158.00

3.4. Materials and methods

3.4.1. Season

The investigation involved two field experiments. First experiment was laid out during late *Samba* season (13.09.2001 to 07.02.2002) and the second experiment during late *Thaladi* season (23.10.2001 to 18.03.2002). The late *Samba* and late *Thaladi* seasons are specific to Karaikal region, which coincides with *Rabi* season of India.

3.4.2. Crop and variety

The medium duration rice variety "Improved *White Ponni*" (*I.W.Ponni*) was selected as the test crop for the field experiments. The parentage of *I.W.Ponni* is the combination of *Taichung 65/2* and *Mayang Ebos-80*. The *I.W.Ponni* variety is medium tall in stature with medium duration of 135-140 days. The grains are medium slender with L/B ratio of 3.22. The colour of leaf sheath and septums are green and that of ligules is white. The auricle is colourless. The panicle is long drooping. The rice kernel colour is white and the abdominal white is absent. The average yield of *I.W.Ponni* variety is 4500 kg ha^{-1}.

3.4.3. Experimental design

The experiments were conducted in split plot design with eight main plot treatments and two subplot treatments totalling 16 treatments, replicated thrice. The field layout plan is given in Fig.1 and Fig.2.

3.4.4. Treatment details

The treatment structure for both the experiments are furnished hereunder.

Mainplots (Age of seedlings and plant population)

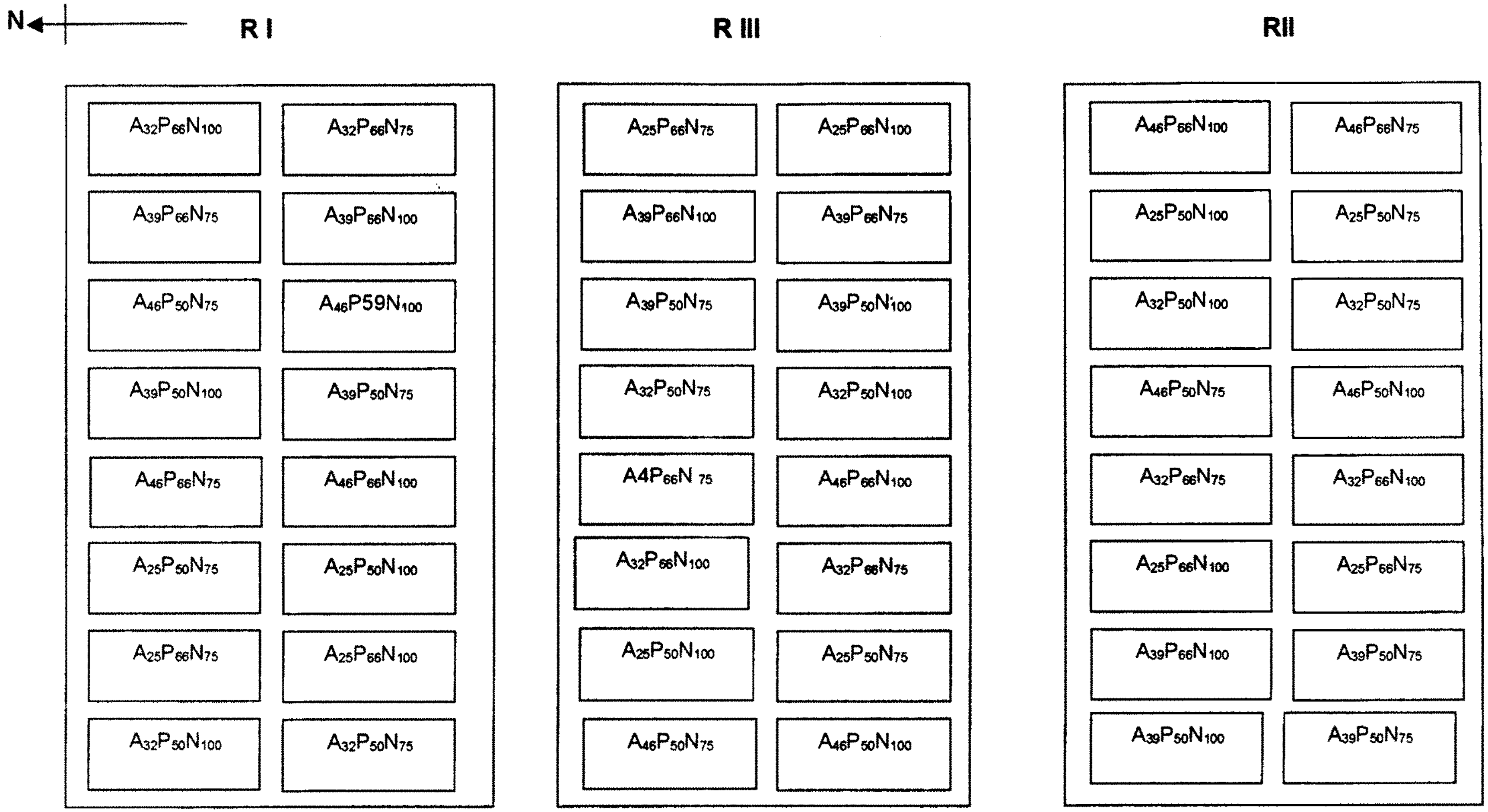
1) Age of seedlings (Four levels)

A_1 – 25 days old seedlings

A_2 – 32 days old seedlings

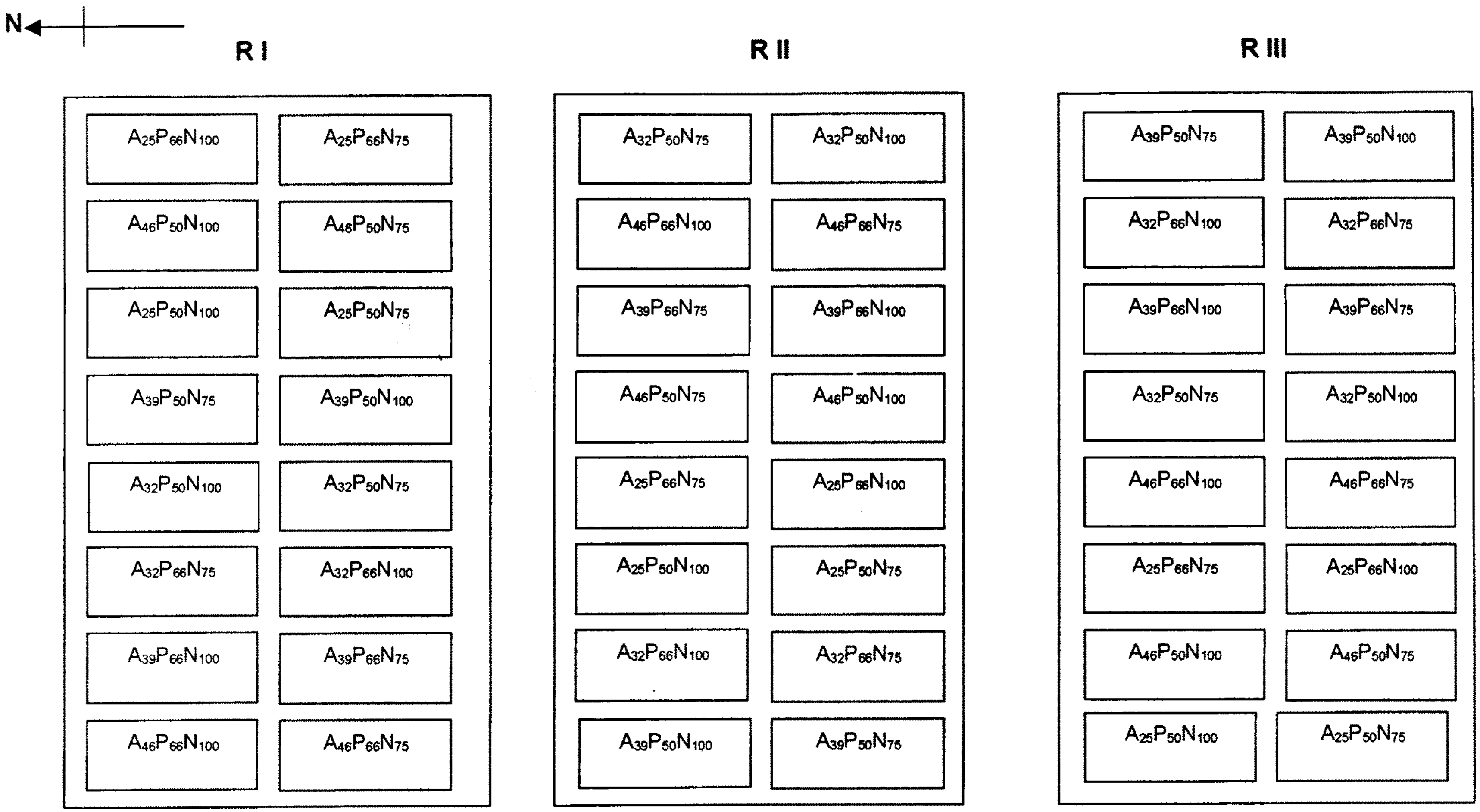
A_3 – 39 days old seedlings

A_4 – 46 days old seedlings



Gross plot size: 5.0 X 4.0 m

Fig.1 Lay out plan of the experiment I



Gross plot: 5.0 X 4.0 m

Fig.2 Lay out plan of the experiment II

2) Plant population (Two levels)

P_1 – 100 per cent of recommended plant population (50 hills m^{-2})

P_2 – 125 per cent of recommended plant population (66 hills m^{-2})

Subplots (N levels)

N_1 – 100 per cent of recommended nitrogen (150:50:50 kg NPK ha^{-1})

N_2 – 75 per cent of recommended nitrogen (112.5:50:50 kg NPK ha^{-1})

The recommended dose of fertilizer for *I.W.Ponni* is 150:50:50 kg NPK ha^{-1}.

3.4.5. Plot size

The gross plot size and net plot size followed for two plant population levels for both the experiments are given below.

Plant population level	Gross plot size	Net plot size
P_1- 20X10 cm (50 hills m^{-2})	5m x 4m	4.2m x 3.6m
P_2- 15x10 cm (66 hills m^{-2})	5m x 4m	4.4m x 3.6m

3.5. Cultivation details

3.5.1. Field preparation

The field was puddled twice with cage wheel using tractor. The field was then laid into beds and channels (irrigation channels cum pathways) as shown in the layout plan (Fig.1 and Fig.2) to have plots of convenient size (5m x 4m).

3.5.2. Sowing

The seeds were treated with carbendazim at the rate of 2 g kg^{-1} of seed to control seed borne diseases and with azospirillum after 24 hours. Then the seeds were soaked in water for one day and incubated in dark room for one day (2nd day). The sprouted seeds were sown in the nursery on third day.

3.5.3. Fertilizer application to nursery

Diammonium phosphate (DAP) application was done at the rate of 2 kg cent $^{-1}$(40 m^{-2}) just at the time of sowing as a basal dose.

3.5.4. Transplanting

The land was prepared and maintained at optimum condition for transplanting. The following were the dates of sowing and dates of transplanting for both the experiments.

Experiment	Date of sowing	Age of seedlings	Date of transplanting
I	13.09.2001	(i) 25 days old	08.10.2001
		(ii) 32 days old	15.10.2001
		(iii) 39 days old	22.10.2001
		(iv) 46 days old	29.10.2001
II	23.10.2001	(i) 25 days old	16.11.2001
		(ii) 32 days old	23.11.2001
		(iii) 39 days old	30.11.2001
		(iv) 46 days old	07.12.2001

Cropping period of experiment I: 13.09.2001 to 07.02.2002

Cropping period of experiment II: 23.10.2001 to 18.03.2002

3.5.6. Fertilizer application

A recommended dose of 150:50:50 kg NPK ha^{-1} was given to N_1 plots (100 per cent of recommended dose of N). Similarly, a fertilizer dose of 112.5:50:50 kg NPK ha^{-1} was given to N_2 plots (75 per cent of recommended dose of N). The N, P and K nutrients were applied as urea, single super phosphate and muriate of potash, respectively. Full dose of phosphorus was applied as basal. At both the levels (N_1 and N_2), nitrogen was applied in four equal splits *viz.*, at 7th day after transplanting, maximum tillering, panicle initiation stage and at 50 percent flowering stage. Potassium was applied in three splits *viz.*, 50 per cent of K as basal dose, 25 percent of K at maximum tillering stage and 25 percent of K at panicle initiation stage along with nitrogen.

3.5.6. Weed management

Butachlor at the rate of 1.0 kg a.i ha^{-1} was applied as pre-emergence herbicide on 6th day after transplanting. One hand weeding was taken up on 35 days after transplanting.

3.5.7. Water management

Irrigation was given as and when needed and there was no water stress throughout the crop period.

3.5.8. Plant protection

There was no disease incidence during the crop period. The incidence of stem borer pest was noticed during panicle initiation stage, for which need based plant protection measures were taken up.

3.5.9. Harvest

The crop was harvested when most of the plants attained physiological maturity. When the late *Samba* crop was ready for harvest, it was caught up with heavy rains and subsequent floods. Hence, harvesting was done from all the plots on 07.02.2002 after draining out excess water, irrespective of age of seedlings (25, 32, 39 and 46 days old seedlings). Otherwise the crop would have been harvested in a staggered manner, if there were not unusual rains. The late *Thaladi* crop was harvested on four different periods *viz.*, on 04.03.2002 (25 days old seedlings) 07.03.2002 (32 days old seedlings), 11.03.2002 (39 days old seedlings) and 18.03.2002 (46 days old seedlings). The plants were hand thrashed plot wise, grains separated, sun dried and weighed.

3.6. Biometric observations

The following biometric observations were taken up during the crop growth period.

3.6.1. Growth attributes

In the net plot area, five hills were selected at random and labelled for biometric observations. The biometric observations were recorded at three stages of the crop *viz.*, 30 days after transplanting (maximum tillering stage), 60 days after transplanting (panicle initiation stage) and at harvest.

3.6.1.1. Plant height

Plant height from the ground to the tip of the plant was measured in the five tagged hills at three stages of crop *viz.*, on 30 and 60 days after transplanting (coinciding with maximum tillering and panicle initiation stages respectively) and at harvest and the mean values were calculated in centimeter (cm).

3.6.1.2. Plant population

The plant population was counted using a quadrat during maximum tillering and panicle initiation stages. The quadrat was placed randomly at four places and plant population was counted in each quadrat. The average plant population per unit area was then calculated.

3.6.1.3. Root length

The total root length was estimated at maximum tillering stage. For this purpose, three hills were selected at random outside the net plot area and then removed carefully without much loss of roots as far as possible and the mean length of the root was measured and expressed in cm.

$$\text{Root length} = \frac{\text{Total length of 10 sample roots (cm)}}{\text{Weight of 10 sample roots (mg)}} \times \text{Total weight of the roots (mg)}$$

3.6.1.4. Root volume

Root volume was estimated at maximum tillering stage. For this purpose, the three hills that removed for measuring root length were used. After measuring root length, the roots were separated and immersed in water of known volume in a measuring cylinder and the increase in volume of water was recorded as root volume and expressed in cubic centimeter (cc).

3.6.1.5. Number of leaves tiller^{-1}

The number of leaves tiller^{-1} was recorded from the five tagged hills at two stages of the crop *viz.*, 30 and 60 days after transplanting coinciding with maximum tillering and panicle initiation stages, respectively.

3.6.1.6.Leaf area index

The length and breadth of the third leaf from the top was measured at two stages of the crop *viz.*, on 30 and 60 DAT from the five hills already tagged and the leaf area index was calculated by the following formula as suggested by Yoshida *et al.* (1976).

$$LAI = \frac{L \times B \times K}{\text{Spacing (cm)}} \times \text{total number of leaves hills m}^{-2}$$

Where, L = Length of the leaf (cm)

B = Breadth of the leaf (cm)

K = Correction factor (0.70)

3.6.1.7.Number of tillers hill^{-1}

Total number of tillers hill^{-1} was recorded from the five tagged hills at three stages of the crop *viz.*, on 30 and 60 days after transplanting and at harvest.

3.6.1.8.Dry matter production

Dry matter production was estimated at three stages of the crop *viz.*, on 30 DAT, 60 DAT and at harvest. For this purpose, five hills that were randomly selected each time out of net plot area and then cut close to the ground. These were dried in shade and again oven dried at 60°C till a constant weight was obtained. The oven dry weight was recorded using an electronic top pan balance and dry matter was expressed in kg ha^{-1}.

3.7. Yield attributes

3.7.1. Productive tillers

The number of productive tillers hill^{-1} was counted at harvest stage from the five hills already tagged and then mean number of productive tillers hill^{-1} was calculated.

3.7.2. Panicle length

Panicle length was measured from five primary panicles collected at random from the five tagged hills and mean length of panicle was calculated and expressed in cm.

3.7.3. Panicle weight

The five primary panicles collected for calculating panicle length were weighed using an electronic balance and mean weight of panicle was calculated and expressed in grams.

3.7.4. Number of filled grains panicle^{-1} and ill filled grains panicle^{-1}

The total number of grains from each of five panicles were separated and sorted into filled and ill filled grains and then mean values panicle^{-1} were arrived at.

3.7.5. Spikelet sterility

The number of ill filled grains per panicle and the total number of spikelets per panicle were used for calculating the spikelet sterility and was expressed in percentage.

$$\text{Spikelet sterility} = \frac{\text{Number of ill filled grains panicle}^{-1}}{\text{Number of spikelets panicle}^{-1}} \times 100$$

3.7.6. Days to 50 per cent flowering

The number of days taken for 50 per cent flowering (flowering of 50 per cent population per plot) was recorded in all the treatments over three replication and the average was arrived at.

3.7.7. Grain yield

Grains obtained from the net plot were cleaned, sun dried and weighed. The grain yield was calculated and expressed in kg ha^{-1}.

3.7.8. Straw yield

After separating the grains, the left over straw from the net plot was sun dried and weighed. The straw yield was calculated and expressed in kg ha^{-1}.

3.7.9. Harvest index

This was found out by calculating the ratio between biological and economic yield in each plot.

$$\text{Harvest index (HI)} = \frac{\text{Economic yield (Grain yield)}}{\text{Total biological yield (Grain + Straw yield)}}$$

3.7.10.Test weight of grain

One lot of sample from the grain yield of each plot was drawn and 1000 grains were counted in an unbiased way (i.e., regardless of grain size) and then weighed and expressed in grams.

3.8. Chemical analysis

3.8.1. Soil analysis

Five soil samples at 15 cm depth were collected at random in the experimental field before transplanting and composite soil sample was obtained by quartering method. Similarly post harvest soil samples were also drawn treatment wise and samples were processed by quartering method. These soil samples were analysed following the standard procedures (Table 4).

3.8.2. Plant analysis

Chemical analysis of plants were carried out only at harvest stage. Oven dried plant samples were grinded using a Wiley mill and used for estimating the NPK content. The per cent concentration of these nutrients were multiplied by the respective dry matter content and their uptake values were arrived at as follows.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Per cent nutrient x Total dry matter yield (kg ha}^{-1}\text{)}}{100}$$

The plant samples were analysed for nitrogen, phosphorus and potassium following the standard procedures (Table 5).

3.9. Economics

Cost of cultivation for all the treatments was worked out on the basis of prevailing input cost and market price of the grain at the time of experimentation. The net income was calculated by deducting the cost of cultivation from the gross return. The benefit cost ratio (BCR) was worked out as follows.

$$\text{Benefit cost ratio} = \frac{\text{Net return (Rs. ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs. ha}^{-1}\text{)}}$$

Table 4. Methods of soil analysis

Sl. No.	Particulars	Method	Author
1.	Particle size analysis	International pipette method	Piper (1950)
2.	Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
3.	Available phosphorus	Olsen's method using 0.5 N $NaHCO_3$ of pH 8.5	Olsen *et al.* (1954)
4.	Available potassium	Neutral normal ammonium acetate extract with Flame photometer	Stanford and English (1949)
5.	Organic carbon	Chromic acid wet digestion method	Walkley and Black (1935)
6.	Electrical conductivity (EC) (Soil: water = 1:2)	Using "ELICO" conductivity bridge	Jackson (1973)
7.	Soil reaction (pH) (Soil: water ratio =1:2)	Using glass electrode in the "ELICO" pH meter	Jackson (1973)

Table 5. Methods of plant analysis

Sl. No.	Nutrient	Method	Author
1.	Nitrogen	Microkjeldhal method	Humphries (1956)
2.	Phosphorus	Triple acid digestion with Vanodomolybdate method	Jackson (1973)
3.	Potassium	Triple acid digestion with Flame photometric method	Stanford and English (1949)

3.10. Statistical analysis

The various biometric observations, the analytical data of soil and plant and the computed data such as yield and yield components etc. were subjected to statistical scrutiny as per the procedures given by Sukhatme and Amble (1985).

RESULTS

CHAPTER 4

RESULTS

Two field experiments were conducted for the present investigation. First experiment was conducted during late *Samba* season (13.9.2001 to 07.02 2002) and the second experiment was conducted during the late *Thaladi* season (23.10.2001to 18.08.2002). *Samba* and *Thaladi* are the local seasons at Karaikal beginning with August and September, respectively. On all India basis, both *Samba* and *Thaladi* coincide with *Rabi* season. The treatments consisted of four ages of seedlings (25, 32, 39 and 46 days old) and two plant population (50 and 66 hills m^{-2}, representing recommended and 33 per cent extra population, respectively) in the main plots as well as two nitrogen levels (100 and 75 per cent recommended dose of nitrogen) in subplots, replicated thrice in a split plot design. The results of the two experiments (two seasons) are presented in this chapter.

4.1. Plant height

4.1.1. Maximum tillering stage (Table 6)

The age of seedlings significantly contributed to the height of the plant in both the seasons. Maximum plant height was recorded due to planting of 25 days old young seedlings followed by 32 and 39 days old seedlings. The plant height was minimum when 46 days old aged seedlings were planted in both the seasons.

Increasing the plant population by 33 per cent over the recommended plant population did not affect the plant height at maximum tillering stage during both seasons. However, nitrogen levels were found to influence the plant height at maximum tillering stage only during the late *Samba* season and not in the late *Thaladi* season. Application of 100 per cent recommended dose of nitrogen (150 kg ha^{-1}) produced taller plants (71.24 cm) than application of 75 per cent recommended dose of nitrogen (112.5 kg ha^{-1}) in which the plant height was 68.78 cm.

The interaction effect between age of seedlings and plant population on plant height was significant only during the late *samba* season and not in the late *Thaladi* season (Table 7). Planting of 25 and 32 days old seedlings resulted in significantly

Table 6. Effect of age of seedlings, plant population and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season: Late *Samba*		Season: Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	74.24		86.50	
A_2: 32 days old	72.53		81.73	
A_3: 39 days old	70.84		77.98	
A_4: 46 days old	62.42		70.65	
SEd	**1.34**		**1.27**	
CD (p = 0.05)	**2.87**		**2.72**	
Plant population (P)				
P_1: 50 hills m^{-2}	70.93		78.70	
P_2: 66 hills m^{-2}	69.09		79.93	
SEd	**0.95**		**0.90**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	71.24		79.48	
N_2: 75 per cent N	68.78		78.96	
SEd	**0.57**		**0.86**	
CD (p = 0.05)	**1.21**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	1.89	4.06	1.80	NS
Population x Nitrogen	1.10	NS	1.24	NS
Nitrogen x Age	1.14	NS	1.71	NS
Nitrogen x Population	0.81	NS	1.21	NS
Age x Nitrogen	1.56	NS	1.76	NS
Age x Population x Nitrogen	1.15	NS	1.48	NS

Table 7. Effect of interaction between age of seedlings and plant population on plant height (cm) of *I.W.Ponni* rice variety at maximum tillering stage (late *Samba* season)

Plant population	Age of seedlings (days)			
	25	**32**	**39**	**46**
P_1: 50 hills m^{-2}	74.81	71.86	70.48	66.57
P_2: 66 hills m^{-2}	73.68	73.21	71.20	58.27
SEd	1.09			
CD (p = 0.05)	4.06**			

taller plants than planting of 39 and 46 days old seedlings under both plant population (50 and 66 hills m^{-2}). The plant height was the lowest when 46 days old seedlings were planted, irrespective of plant density during late *samba* season.

The other interaction effects (between population and nitrogen, age and nitrogen; three way interaction of A x P x N) did not affect the plant height significantly at maximum tillering stage during both seasons. The over all plant height was taller during late *Thaladi* season than late *Samba* season, irrespective of plant population and nitrogen levels (Table 6 and Fig.3).

4.1.2. Panicle initiation stage (Table 8)

As observed in maximum tillering stage, the age of seedlings were also found to influence the plant height at panicle initiation stage during both seasons. Planting of 25 days old young seedlings gave significantly taller plants than planting of 32 and 39 days old seedlings. The plant height was the lowest when 46 days old aged seedlings were planted during both seasons.

Either increasing plant population by 33 per cent or reducing of fertilizer nitrogen by 25 per cent did not affect the plant height significantly at panicle initiation stage during both seasons.

All the interaction effects, except the interaction between age and nitrogen, did not affect the plant height significantly at panicle initiation stage during both seasons. The interaction between age and nitrogen during late *Thaladi* season had significantly influenced the plant height (Table 9). When 100 per cent nitrogen was applied, planting of 25 to 39 days old seedlings gave significantly taller plants and their plant height were on par. Significantly, the lowest plant height was obtained even with 100 per cent nitrogen when 46 days old seedlings were planted. When the nitrogen was reduced by 25 per cent (75% N was applied) almost similar trend was observed, with significantly taller plants due to planting of 25 days old young seedlings than planting of 32 and 39 days old seedlings and their plant height was on par. The lowest plant height was recorded when 46 days old aged seedlings were planted. Except 32 days old seedlings, seedlings of all other ages (25,39 and 46 days old) gave statistically comparable plant height at both the levels of nitrogen. Planting of 32 days old seedlings gave the shortest plants at 75 per cent nitrogen.

Table 8. Effect of age of seedlings, plant population and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at panicle initiation stage

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	100.05	101.42
A_2: 32 days old	94.22	95.05
A_3: 39 days old	98.65	92.00
A_4: 46 days old	88.63	75.88
SEd	**1.58**	**2.54**
CD (p = 0.05)	**3.39**	**5.45**
Plant population (P)		
P_1: 50 hills m^{-2}	95.11	89.71
P_2: 66 hills m^{-2}	95.67	92.47
SEd	**1.12**	**1.80**
CD (p = 0.05)	**NS**	**NS**
Nitrogen levels (N)		
N_1: 100 per cent N	96.62	91.34
N_2: 75 per cent N	94.16	90.83
SEd	**1.18**	**1.46**
CD (p = 0.05)	**Ns**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	2.24	NS	3.59	NS
Population x Nitrogen	1.63	NS	2.31	NS
Nitrogen x Age	2.36	NS	2.92	6.18
Nitrogen x Population	1.67	NS	2.06	NS
Age x Nitrogen	2.30	NS	3.27	6.98
Age x Population x Nitrogen	1.98	NS	2.64	NS

Table 9. Effect of interaction between age of seedlings and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at panicle initiation stage (late *Thaladi* season)

Nitrogen levels	**Age of seedlings (days)**			
	25	**32**	**39**	**46**
N_1: 100 per cent nitrogen	99.37	94.73	93.63	73.63
N_2 : 75 per cent nitrogen	103.47	91.37	90.37	78.13
	A at N		N at A	
SEd	3.27		2.92	
CD (p = 0.05)	6.98**		6.18**	

It was quite interesting to observe that unlike in the maximum tillering stage, where the overall plant height was taller in late *Thaladi* season than late *Samba* season, the trend was quite reverse at panicle initiation stage. That is the plant height was slightly shorter during late *Thaladi* season than late *Samba* season at panicle initiation stage due to different plant population, varying levels of nitrogen when planted with 39 and 46 days old seedlings (Fig.4). However, when young seedlings of 25 and 32 days old were planted, there was not much difference in plant height between the two seasons at panicle initiation stage.

4.1.3. Harvest stage (Table 10)

It was also quite interesting to observe that the plant height was influenced significantly only during late *Samba* season by various treatments. During late *Thaladi* season the plant height was not influenced significantly by the various treatments.

The plant height was significantly taller due to planting of 39 days old (123.62cm) and 25 days old seedlings (121.15 cm), which were on par. This was followed by 32 days old seedlings (115.48 cm) and the lowest plant height was obtained due to planting of 46 days old seedlings (111.32 cm) during late *Samba* season. The plants were significantly taller when 100 per cent nitrogen was applied (120.14 cm) than 75 per cent nitrogen (115.64cm) during late *Samba* season.

The plant population as well as its interaction effect with age of seedlings did not influence the plant height significantly during late *Samba* season. The nitrogen levels and its interaction with age of seedlings (Table 11) and the interaction between nitrogen levels and plant population (Table 12) were found to influence the plant height significantly at harvest stage.

The interaction between age of seedlings and nitrogen levels (Table 11) revealed that at 100 per cent nitrogen, the plant height was on par due to planting of 39 days (126.83 cm) and 25 days (123.83 cm) old seedlings and they were taller than planting of 32 days (113.80 cm) and 46 days (117.30 cm) old seedlings which were on par. However, at 75 per cent nitrogen, planting of 25,32 and 39 days old seedlings were found to produce tall plants (119.13, 117.70 and 120.40 cm,

Table 10. Effect of age of seedlings, plant population and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	121.15	129.83
A_2: 32 days old	115.48	126.17
A_3: 39 days old	123.62	131.18
A_4: 46 days old	111.32	130.37
SEd	**1.45**	**2.28**
CD (p = 0.05)	**3.12**	**NS**
Plant population (P)		
P_1: 50 hills m^{-2}	112.47	130.99
P_2: 66 hills m^{-2}	110.17	127.78
SEd	**1.03**	**1.61**
CD (p = 0.05)	**NS**	**NS**
Nitrogen levels (N)		
N_1: 100 per cent N	120.14	129.31
N_2: 75 per cent N	115.64	129.47
SEd	**0.83**	**1.81**
CD (p = 0.05)	**1.77**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	2.06	NS	3.22	NS
Population x Nitrogen	1.32	2.83	2.42	NS
Nitrogen x Age	1.67	3.53	3.62	NS
Nitrogen x Population	1.18	2.50	2.56	NS
Age x Nitrogen	1.87	3.99	3.43	NS
Age x Population x Nitrogen	1.51	3.21	3.01	NS

Table 11. Effect of interaction between age of seedlings and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at harvest stage (late *Samba* season)

Nitrogen level	**Age of seedlings (days)**			
	25	**32**	**39**	**46**
N_1: 100 per cent nitrogen	123.83	113.80	126.83	117.30
N_2: 75 per cent nitrogen	119.13	117.70	120.40	105.33
	A at N		N at A	
SEd	1.87		1.67	
CD (p=0.05%)	3.99**		3.53**	

Table 12. Effect of interaction between plant population and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at harvest stage (late *Samba* season)

Nitrogen level	**Plant population**	
	P_1: 50 hills m^{-2}	**P_2: 66 hills m^{-2}**
N_1: 100 per cent nitrogen	122.21	118.07
N_2: 75 per cent nitrogen	115.67	115.62
	N at P	P at N
SEd	1.18	1.32
CD (p=0.05%)	2.50*	2.83*

respectively) which were on par and they were significantly taller than planting of 46 days old seedlings (105.33 cm). Except 32 days old seedlings which gave rise to taller plants at 75 per cent nitrogen (117.70 cm) than at 100 per cent nitrogen (113.80 cm), all other ages of seedlings (25,39 and 46 days old) were found to produce taller plants (123.83, 126.83 and 117.30 cm, respectively) at 100 per cent nitrogen than at 75 per cent nitrogen (119.13,120.40 and 105.33 cm, respectively). But planting of 46 days old aged seedlings resulted in the lowest plant height at both the levels of nitrogen.

The interaction between plant population and nitrogen (Table 12) revealed that at 100 per cent nitrogen dose, recommended plant population of 50 hills m^{-2} produced taller plants (122.21 cm) than at 33 per cent higher plant population (118.07 cm). However, at 75 per cent nitrogen level the plant height did not differ between the plant population (115.67 and 115.62 cm, respectively at 50 and 66 hills m^{-2}).

When the plant population was at 50 hills m^{-2}, they gave taller plants at 100 per cent nitrogen (122.21 cm) than at 75 per cent nitrogen (115.67 cm). When the population was increased by 33 per cent (66 hills m^{-2}), they gave comparable plant height at both levels of nitrogen (118.07 cm and 115.62 cm, respectively at 100 and 75 % N).

The three-way interaction (AxPxN) was also significant with significantly taller plants due to planting of 39 days old seedlings at both levels of plant population with 100 per cent nitrogen. This was followed by planting of 25 days old seedling with recommended plant population of 50 hills m^{-2} at 100 per cent nitrogen. Planting of 46 days old seedlings gave the lowest plant height with 75 per cent nitrogen at both the levels of plant population (Table 13).

It was very interesting to observe from pooled analysis that at harvest stage, the overall plant height due to various treatments (age of seedlings, plant population and nitrogen levels) was significantly taller during late *Thaladi* season (129.39 cm) than late *Samba* season (117.89 cm) (Table 14). Comparison of the over all plant height between the two seasons also revealed that 46 days old seedlings registered the lowest plant height during late *Samba* season and 32 days old seedling gave the lowest plant height during late *Thaladi* season (Table 10 and Fig.5).

Table 13. Effect of interaction between age of seedlings, plant population and nitrogen levels on plant height (cm) of *I.W.Ponni* rice variety at harvest stage (late *samba*)

Population + nitrogen levels	Age of seedlings (days)			
	25	32	39	46
P_1N_1 (50 hills m^{-2} + 100 % N)	125.47	113.67	128.40	121.83
P_1N_2 (50 hills m^{-2} + 75 % N)	116.47	120.67	121.60	103.60
P_2N_1 (66 hills m^{-2} + 100 % N)	120.87	112.87	125.27	113.27
P_2N_2 (50 hills m^{-2} + 75 % N)	121.17	114.73	119.20	107.07
SEd	1.51			
CD (p=0.05)	3.21**			

Table 14. Effect of seasons and treatments on the plant height (cm) of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	125.47	129.40	127.43
$A_{25}P_{50}N_{75}$	116.80	134.40	125.60
$A_{25}P_{66}N_{100}$	120.87	126.40	123.63
$A_{25}P_{66}N_{75}$	121.47	129.13	125.30
$A_{32}P_{50}N_{100}$	113.67	123.87	118.77
$A_{32}P_{50}N_{75}$	120.67	126.73	132.70
$A_{32}P_{66}N_{100}$	112.87	129.33	121.10
$A_{32}P_{66}N_{75}$	114.73	124.73	119.73
$A_{39}P_{50}N_{100}$	128.40	132.93	130.67
$A_{39}P_{50}N_{75}$	121.60	131.00	126.30
$A_{39}P_{66}N_{100}$	125.27	133.40	129.33
$A_{39}P_{66}N_{75}$	119.20	127.40	123.17
$A_{46}P_{50}N_{100}$	121.33	135.00	128.17
$A_{46}P_{50}N_{75}$	103.60	134.60	119.10
$A_{46}P_{66}N_{100}$	113.27	124.13	118.70
$A_{46}P_{66}N_{75}$	107.07	127.73	117.40
Mean	117.89	129.39	123.64

	SEd	CD (p = 0.05)
Treatment	4.99	NS
Season	1.34	3.71
Treatment x season	3.90	2.77

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

4.2. Total root length $hill^{-1}$ at maximum tillering stage (Table 15)

There was variation in total root length due to age of seedlings only in late *Thaladi* season, with the highest root length due to planting of 32 days old seedlings (7496cm), which was on par with that of 25 days old seedlings (5988cm) and significantly superior to that of 39 days old seedlings (4276cm). The lowest root length was obtained due to planting of 46 days old seedlings (3337 cm).

The variation in root length was significant due to variation in plant population during both seasons, with more total root length in recommended plant population of 50 hills m^{-2} (9840 and 6350 cm, respectively in late *Samba* and late *Thaladi* seasons) than at higher plant population of 66 hills m^{-2} (8064 and 4199 cm, respectively in late *Samba* and late *Thaladi* seasons). The N levels and the various interaction effects (AxP, PxN, AxN and AxPxN) did not affect the total root length significantly during both seasons.

4.3. Root volume $hill^{-1}$ at maximum tillering stage (Table 16)

The root volume $hill^{-1}$ was significantly influenced by age of seedlings only during late *Thaladi* season and by plant population during late *Samba* season. Planting of 25,32,and 39 days old seedlings gave more root volume and they were on par (12.42, 12.36 and 11.05 cc, respectively). Significantly, the lowest root volume was recorded due to planting of 46 days old aged seedlings (8.11cc) during late *Thaladi* season.

Recommended plant population of 50 hills m^{-2} produced higher root volume (19.67 cc) than increased plant population of 66 hills m^{-2} (16.35cc). The nitrogen levels and other interaction effects (AxP, PxN, AxN and AxPxN) did not affect the root volume hill $^{-1}$ significantly during both seasons.

4.4. Number of leaves $tiller^{-1}$

4.4.1. Maximum tillering stage (Table 17)

The number of leaves $tiller^{-1}$ was influenced significantly by age of seedlings during late *Samba* season but not during late *Thaladi* season. Planting of 46 days old seedlings gave more number of leaves $tiller^{-1}$ (4.67) and it was significantly

Table 15. Effect of age of seedlings, plant population and nitrogen levels on total root length $hill^{-1}$ (cm) of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	9656		5988	
A_2: 32 days old	9196		7496	
A_3: 39 days old	9617		4276	
A_4: 46 days old	7339		3337	
SEd	**876**		**1150**	
CD (p = 0.05)	**NS**		**2466**	
Plant population (P)				
P_1: 50 hills m^{-2}	9840		6350	
P_2: 66 hills m^{-2}	8064		4199	
SEd	**620**		**813**	
CD (p = 0.05)	**1329**		**1744**	
Nitrogen levels (N)				
N_1: 100 per cent N	8812		5246	
N_2: 75 per cent N	9092		5303	
SEd	**753**		**428**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	1239	NS	1626	NS
Population x Nitrogen	975	NS	919	NS
Nitrogen x Age	1506	NS	856	NS
Nitrogen x Population	1065	NS	605	NS
Age x Nitrogen	1379	NS	1299	NS
Age x Population x Nitrogen	1231	NS	920	NS

Table 16. Effect of age of seedlings, plant population and nitrogen levels on root volume hill $^{-1}$ (cc) of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	16.75	12.42
A_2: 32 days old	17.11	12.36
A_3: 39 days old	20.75	11.05
A_4: 46 days old	17.42	8.11
SEd	**1.72**	**0.89**
CD (p = 0.05)	**NS**	**1.92**
Plant population (P)		
P_1: 50 hills m^{-2}	19.67	11.39
P_2: 66 hills m^{-2}	16.35	10.58
SEd	**1.21**	**0.63**
CD (p = 0.05)	**2.60**	**NS**
Nitrogen levels (N)		
N_1: 100 per cent N	18.29	11.09
N_2: 75 per cent N	17.72	10.87
SEd	**1.17**	**0.74**
CD (p = 0.05)	**NS**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	2.43	NS	1.26	NS
Population x Nitrogen	1.69	NS	0.97	NS
Nitrogen x Age	2.35	NS	1.48	NS
Nitrogen x Population	1.66	NS	1.05	NS
Age x Nitrogen	2.39	NS	1.38	NS
Age x Population x Nitrogen	2.02	NS	1.22	NS

Table 17. Effect of age of seedlings, plant population and nitrogen levels on the number of leaves tiller^{-1} of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	3.63		3.82	
A_2: 32 days old	3.87		3.70	
A_3: 39 days old	3.63		3.88	
A_4: 46 days old	4.67		3.57	
SEd	**0.13**		**0.18**	
CD (p = 0.05)	**0.28**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	4.03		3.77	
P_2: 66 hills m^{-2}	3.87		3.72	
SEd	**0.09**		**0.13**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	4.03		3.74	
N_2: 75 per cent N	3.87		3.74	
SEd	**0.06**		**0.12**	
CD (p = 0.05)	**0.13**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.18	NS	0.26	NS
Population x Nitrogen	0.11	NS	0.18	NS
Nitrogen x Age	0.13	NS	0.24	NS
Nitrogen x Population	0.19	NS	0.17	NS
Age x Nitrogen	0.16	NS	0.25	NS
Age x Population x Nitrogen	0.12	NS	0.21	NS

higher than that of 25, 32 and 39 days old seedlings (3.63, 3.87 and 3.63 leaves tiller^{-1}, respectively).

The plant population did not influence the number of leaves tiller^{-1} during both the seasons. The nitrogen levels were found to influence the number of leaves tiller^{-1} significantly only during late *Samba* season but not during late *Thaladi* season. Application of recommended dose of nitrogen (100% N) gave more number of leaves tiller^{-1} (4.03) than 75 per cent nitrogen (3.87). The other interactions (AxP, AxN and AxPxN) did not affect the number of leaves tiller^{-1} significantly during both the seasons.

4.4.2. Panicle initiation stage (Table 18)

The age of seedlings, plant population, nitrogen levels and their interactions did not affect the number of leaves tiller^{-1} significantly during both the seasons. The number of leaves tiller^{-1} ranged from 4.82 to 4.93 during late *Samba* season and from 3.98 to 4.03 during late *Thaladi* season.

4.5. Leaf area index

4.5.1. Maximum tillering stage (Table 19)

The age of seedlings did not influence the leaf area index during late *Samba* season. But it influenced the same during late *Thaladi* season. Planting of 25 days old young seedlings gave significantly higher leaf area index (3.34), followed by 32 and 39 days old seedlings (2,94 and 2.88, respectively) and the lowest leaf area index (2.20) was registered by planting of 46 days old seedlings.

The leaf area index was influenced significantly by plant population during both seasons, with the highest leaf area index (3.45 and 3.00 during late *Samba* season and late *Thaladi* season, respectively) due to increasing the plant population by 33 per cent (66 hills m^{-2}) and the lowest leaf area index (2.99 and 2.68 during late *Samba* and late *Thaladi* seasons, respectively) was registered in recommended plant population of 50 hills m^{-2}.

The nitrogen level influenced the leaf area index significantly only during late *Samba* season with the highest leaf area index at 100 per cent nitrogen (3.41), and

Table 18. Effect of age of seedlings, plant population and nitrogen levels on the number of leaves tiller^{-1} of *I.W.Ponni* rice variety at panicle initiation stage

Treatments	**Season**			
	Late *Samba*		**Late *Thaladi***	
Age of seedlings (A)				
A_1: 25 days old	4.92		3.90	
A_2: 32 days old	4.87		4.03	
A_3: 39 days old	4.82		3.93	
A_4: 46 days old	4.93		3.95	
SEd	**0.16**		**0.07**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	4.90		3.97	
P_2: 66 hills m^{-2}	4.87		3.95	
SEd	**0.11**		**0.04**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	4.83		3.98	
N_2: 75 per cent N	4.93		3.94	
SEd	**0.09**		**0.04**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.23	NS	0.10	NS
Population x Nitrogen	0.15	NS	0.06	NS
Nitrogen x Age	0.19	NS	0.08	NS
Nitrogen x Population	0.14	NS	0.06	NS
Age x Nitrogen	0.21	NS	0.09	NS
Age x Population x Nitrogen	0.17	NS	0.07	NS

Table 19. Effect of age of seedlings, plant population and nitrogen levels on the leaf area index of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	3.12		3.34	
A_2: 32 days old	3.29		2.94	
A_3: 39 days old	3.09		2.88	
A_4: 46 days old	3.40		2.20	
SEd	**0.18**		**0.18**	
CD (p = 0.05)	**NS**		**0.38**	
Plant population (P)				
P_1: 50 hills m^{-2}	2.99		2.68	
P_2: 66 hills m^{-2}	3.45		3.00	
SEd	**0.13**		**0.13**	
CD (p = 0.05)	**0.28**		**0.27**	
Nitrogen levels (N)				
N_1: 100 per cent N	3.41		2.86	
N_2: 75 per cent N	3.03		2.82	
SEd	**0.12**		**0.10**	
CD (p = 0.05)	**0.25**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.26	NS	0.25	NS
Population x Nitrogen	0.18	NS	0.16	NS
Nitrogen x Age	0.24	NS	0.21	NS
Nitrogen x Population	0.17	NS	0.15	NS
Age x Nitrogen	0.25	NS	0.23	NS
Age x Population x Nitrogen	0.21	NS	0.19	NS

the lowest leaf area index at 75 per cent nitrogen (3.03). However, the nitrogen levels did not influence the leaf area index during late *Thaladi* season.

The various interaction effects (AxP, PxN, AxN and AxPxN) did not influence the leaf area index significantly during both seasons. The pooled analysis of the leaf area index during maximum tillering stage (Table 20) revealed that the overall effect of the treatments did not influence the leaf area index significantly. Similarly, the season/climate did not affect the leaf area index significantly. However, the treatment and seasonal interaction was found to influence the leaf area index significantly. Planting of 39 days old seedlings at 33 per cent increased plant population with 75 per cent nitrogen; and planting of 46 days old seedlings at both plant population and nitrogen levels, gave significantly higher leaf area index during late *Samba* season than during late *Thaladi* season. The other treatments (25,32 days old seedling at both plant population and nitrogen levels and 39 days old seedling at 100 per cent plant population and at both levels of nitrogen) gave comparable leaf area index, during both the seasons.

4.5.2. Panicle initiation stage (Table 21)

During late *Samba* season, the age of seedling did not affect the leaf area index significantly. However, it influenced the leaf area index during late *Thaladi* season. Planting of young seedlings of 25 and 32 days old were found to register more leaf area index (5.43 and 5.32, respectively) than planting of 39 and 49 days old seedlings (4.83 and 4.82, respectively).

Similarly, during late *Samba* season the plant population did not influence the leaf area index but the same was influenced by plant population during late *Thaladi* season, with the highest leaf area index (5.32) due to increase of plant population by 33 per cent (66 hills m^{-2}) than recommended plant population of 50 hills m^{-2} (4.88).

The nitrogen level and the other interaction effects (AxP, PxN, AxN and AxPxN) did not affect the LAI significantly at panicle initiation stage during both the seasons. The pooled analysis of leaf area index (Table 22) during panicle initiation stage revealed that neither the treatment nor the season or the interaction between them affected the leaf area index significantly.

Table 20. Effect of seasons and treatments on the leaf area index of *I.W.Ponni* rice variety at maximum tillering stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	3.35	3.15	3.25
$A_{25}P_{50}N_{75}$	2.68	2.97	2.83
$A_{25}P_{66}N_{100}$	3.57	3.69	3.63
$A_{25}P_{66}N_{75}$	2.87	3.53	3.20
$A_{32}P_{50}N_{100}$	2.93	2.78	2.86
$A_{32}P_{50}N_{75}$	3.08	2.78	2.93
$A_{32}P_{66}N_{100}$	3.62	3.08	3.35
$A_{32}P_{66}N_{75}$	3.43	3.14	3.29
$A_{39}P_{50}N_{100}$	3.10	2.77	2.94
$A_{39}P_{50}N_{75}$	2.47	2.81	2.64
$A_{39}P_{66}N_{100}$	3.63	2.95	3.29
$A_{39}P_{66}N_{75}$	3.17	3.00	3.09
$A_{46}P_{50}N_{100}$	3.42	2.09	2.76
$A_{46}P_{50}N_{75}$	2.87	2.11	2.49
$A_{46}P_{66}N_{100}$	3.65	2.37	3.01
$A_{46}P_{66}N_{75}$	3.68	2.23	2.95
Mean	3.22	2.84	3.03

	SEd	CD (p = 0.05)
Treatment	0.42	NS
Season	0.20	NS
Treatment x season	0.34	0.67

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

Table 21. Effect of age of seedlings, plant population and nitrogen levels on the leaf area index of *I.W.Ponni* rice variety at panicle initiation stage

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	4.85	5.43
A_2: 32 days old	4.65	5.32
A_3: 39 days old	5.12	4.83
A_4: 46 days old	4.60	4.82
SEd	**0.25**	**0.17**
CD (p = 0.05)	**NS**	**0.37**
Plant population (P)		
P_1: 50 hills m^{-2}	4.63	4.88
P_2: 66 hills m^{-2}	4.98	5.32
SEd	**0.18**	**0.12**
CD (p = 0.05)	**NS**	**0.26**
Nitrogen levels (N)		
N_1: 100 per cent N	4.72	5.17
N_2: 75 per cent N	4.88	5.03
SEd	**0.13**	**0.15**
CD (p = 0.05)	**NS**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.35	NS	0.24	NS
Population x Nitrogen	0.22	NS	0.19	NS
Nitrogen x Age	0.26	NS	0.30	NS
Nitrogen x Population	0.19	NS	0.21	NS
Age x Nitrogen	0.31	NS	0.27	NS
Age x Population x Nitrogen	0.25	NS	0.24	NS

Table 22. Effect of seasons and treatments on the leaf area index of *I.W.Ponni* rice variety at panicle initiation stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	4.61	5.14	4.88
$A_{25}P_{50}N_{75}$	5.17	5.64	5.40
$A_{25}P_{66}N_{100}$	4.63	5.64	5.14
$A_{25}P_{66}N_{75}$	4.97	5.29	5.13
$A_{32}P_{50}N_{100}$	4.67	5.26	4.97
$A_{32}P_{50}N_{75}$	4.15	4.82	4.48
$A_{32}P_{66}N_{100}$	5.10	5.63	5.36
$A_{32}P_{66}N_{75}$	4.67	5.58	5.13
$A_{39}P_{50}N_{100}$	4.51	4.72	4.62
$A_{39}P_{50}N_{75}$	4.94	4.52	4.73
$A_{39}P_{66}N_{100}$	5.43	5.23	5.33
$A_{39}P_{66}N_{75}$	5.61	4.83	5.22
$A_{46}P_{50}N_{100}$	4.40	4.66	4.53
$A_{46}P_{50}N_{75}$	4.59	4.29	4.44
$A_{46}P_{66}N_{100}$	4.43	5.09	4.76
$A_{46}P_{66}N_{75}$	4.96	5.25	5.11
Mean	4.80	5.10	4.95

	SEd	CD (p = 0.05)
Treatment	0.35	NS
Season	0.16	NS
Treatment x season	0.41	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

4.6. Number of tillers hill^{-1}

4.6.1. Maximum tillering stage (Table 23)

The number of tillers hill^{-1} was not affected by the age of seedlings during late *Samba* season. However, it was influenced by age of seedlings during late *Thaladi* season. Planting of 25, 32 an 39 days old seedlings were found to have statistically comparable number of tillers hill^{-1} (7.28, 6.47 and 6.33, respectively) and they were higher than planting of 46 days old seedlings which had the lowest number of tillers hill^{-1} (5.08).

The number of tillers hill^{-1} was affected by plant population significantly during late *Samba* season and not during late *Thaladi* season. Planting of recommended plant population (50 hills m^{-2}) was found to register more number of tillers hill^{-1} (9.51) than that of 33 per cent increased plant population (66 hills m^{-2}), during late *Samba* season (8.58).

Similarly, the nitrogen level was found to alter the number of tillers hill^{-1} only during late *Samba* season and not during late *Thaladi* season. Recommended dose of 100 per cent nitrogen gave more number of tillers hill^{-1} (9.38) than 75 per cent nitrogen (8.71) during late *Samba* season.

The various interaction effects (AxP, PxN, AxN and AxPxN) did not influence the number of tillers hill^{-1} during both the seasons. The overall comparison of number of tillers hill^{-1} between the seasons revealed that during late *Thaladi* season the number of tillers hill^{-1} were relatively lesser than late *Samba* season in all the treatments (Fig.8).

4.6.2. Panicle initiation stage (Table 24)

The number of tillers hill^{-1} did not vary due to age of seedlings during late *Samba* season and it varied during late *Thaladi* season. Planting of 25 and 32 days old seedlings produced higher number of tillers hill^{-1} (8.77 and 8.56, respectively) than 39 and 46 days old seedlings (7.45 and 7.98, respectively).

During late *Samba* season the number of tillers hill^{-1} were influenced by plant population and not during the late *Thaladi* season. Recommended plant population of 50 hills m^{-2} gave significantly higher number of tillers hill^{-1} (9.01) than planting of 33 per cent extra seedlings (66 hills m^{-2}) during late *Samba* season (7.77).

Table 23. Effect of age of seedlings, plant population and nitrogen levels on the number of tillers hill^{-1} of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	9.05		7.28	
A_2: 32 days old	9.02		6.47	
A_3: 39 days old	9.55		6.33	
A_4: 46 days old	8.55		5.08	
SEd	**0.48**		**0.49**	
CD (p = 0.05)	**NS**		**1.04**	
Plant population (P)				
P_1: 50 hills m^{-2}	9.51		6.30	
P_2: 66 hills m^{-2}	8.58		6.28	
SEd	**0.34**		**0.34**	
CD (p = 0.05)	**0.72**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	9.38		6.38	
N_2: 75 per cent N	8.71		6.20	
SEd	**0.22**		**0.29**	
CD (p = 0.05)	**0.46**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.67	NS	0.69	NS
Population x Nitrogen	0.40	NS	0.45	NS
Nitrogen x Age	0.44	NS	0.58	NS
Nitrogen x Population	0.31	NS	0.41	NS
Age x Nitrogen	0.57	NS	0.64	NS
Age x Population x Nitrogen	0.43	NS	0.52	NS

Table 24. Effect of age of seedlings, plant population and nitrogen levels on the number of tillers hill^{-1} of *I.W.Ponni* rice variety at panicle initiation stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	8.12		8.77	
A_2: 32 days old	8.13		8.56	
A_3: 39 days old	8.80		7.45	
A_4: 46 days old	8.50		7.98	
SEd	**0.41**		**0.41**	
CD (p = 0.05)	**NS**		**0.89**	
Plant population (P)				
P_1: 50 hills m^{-2}	9.01		8.35	
P_2: 66 hills m^{-2}	7.77		8.03	
SEd	**0.29**		**0.29**	
CD (p = 0.05)	**0.62**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	8.19		8.29	
N_2: 75 per cent N	8.58		8.09	
SEd	**0.39**		**0.49**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.57	NS	0.59	NS
Population x Nitrogen	0.49	NS	0.57	NS
Nitrogen x Age	0.78	NS	0.97	NS
Nitrogen x Population	0.55	NS	0.69	NS
Age x Nitrogen	0.69	NS	0.80	NS
Age x Population x Nitrogen	0.63	NS	0.76	NS

The nitrogen levels and other interaction effects (AxP, PxN AxN and AxPxN) did not increase the number of tillers $hill^{-1}$ significantly. There was not much variation between the seasons in respect of number of tillers $hill^{-1}$ under various treatments (Fig.9)

4.6.3. Harvest stage (Table 25)

The number of tillers $hill^{-1}$ was only influenced by the age of seedlings during late *Thaladi* season and not during the late *Samba* season. Planting of 25,32 and 46 days old seedlings gave higher number of tillers $hill^{-1}$ (7.47,7.12 and 6.72, respectively) which were on par and they were superior to planting of 39 days old seedlings that gave the lowest number of tillers $hill^{-1}$ (5.50) during late *Thaladi* season.

The plant population also influenced the number of tillers $hill^{-1}$ Recommended plant population of 50 hills m^{-2} gave more number of tillers $hill^{-1}$ (7.23) than increasing the plant population by 33 per cent (66 hills m^{-2}) during late *Samba* season (6.28).

The nitrogen levels and other interaction effects (AxP, PxN, AxN and AxPxN) did not affect the number of tillers $hill^{-1}$ during both the seasons. There was not much variation in the number of tillers $hill^{-1}$ among various treatments between the seasons (Fig.10).

4.7. Dry matter production

4.7.1. Maximum tillering stage (Table 26)

The total dry matter production at maximum tillering stage was influenced significantly by age of seedlings during both the seasons. Planting of 25 days old young seedlings produced the higher dry matter (4023,3912 kg ha^{-1} during late *Samba* and late *Thaladi* seasons, respectively), followed by 32 days old seedlings (3637,3730 kg ha^{-1}, respectively during late *Samba* and late *Thaladi* seasons) and 39 days old seedlings (3221, 2907 kg ha^{-1} respectively during late *Samba* and late *Thaladi* seasons). The lowest dry matter production was realized due to planting of 46 days old seedlings (2657 and 2098 kg ha^{-1}, respectively during late *Samba* and late *Thaladi* seasons).

Table 25. Effect of age of seedlings, plant population and nitrogen levels on the number of tillers $hill^{-1}$ of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	6.53		7.47	
A_2: 32 days old	6.60		7.12	
A_3: 39 days old	6.95		5.50	
A_4: 46 days old	6.93		6.72	
SEd	**0.39**		**0.44**	
CD (p = 0.05)	**NS**		**0.94**	
Plant population (P)				
P_1: 50 hills m^{-2}	7.23		7.02	
P_2: 66 hills m^{-2}	6.28		6.38	
SEd	**0.28**		**0.31**	
CD (p = 0.05)	**0.61**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	6.83		6.75	
N_2: 75 per cent N	6.68		6.65	
SEd	**0.35**		**0.27**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.57	NS	0.62	NS
Population x Nitrogen	0.45	NS	0.42	NS
Nitrogen x Age	0.70	NS	0.55	NS
Nitrogen x Population	0.50	NS	0.39	NS
Age x Nitrogen	0.34	NS	0.59	NS
Age x Population x Nitrogen	0.57	NS	0.49	NS

Table 26. Effect of age of seedlings, plant population and nitrogen levels on dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at maximum tillering stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	4023		3912	
A_2: 32 days old	3637		3730	
A_3: 39 days old	3221		2907	
A_4: 46 days old	2657		2098	
SEd	**126**		**189**	
CD (p = 0.05)	**270**		**404**	
Plant population (P)				
P_1: 50 hills m^{-2}	3188		3034	
P_2: 66 hills m^{-2}	3581		3289	
SEd	**89**		**133**	
CD (p = 0.05)	**191**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	3592		3328	
N_2: 75 per cent N	3177		2995	
SEd	**62**		**136**	
CD (p = 0.05)	**131**		**288**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	178	NS	267	572
Population x Nitrogen	108	NS	190	NS
Nitrogen x Age	124	NS	271	NS
Nitrogen x Population	87	NS	192	NS
Age x Nitrogen	153	NS	269	NS
Age x Population x Nitrogen	118	NS	231	NS

The plant population had significant impact on dry matter production only during late *Samba* season and not during late *Thaladi* season. Increasing the plant population by 33 per cent (66 hills m^{-2}) produced the highest dry matter production (3581 kg ha^{-1}) than recommended plant population of 50 hills m^{-2} (3188 kg ha^{-1}), during late *Samba* season.

The nitrogen levels were found to manipulate the dry matter production during both the seasons with the highest dry matter production at 100 per cent nitrogen (3592 and 3328 kg ha^{-1} during late *Samba* and late *Thaladi* seasons respectively) than at 75 per cent nitrogen (3177and 2995 kg ha^{-1} during late *Samba* and late *Thaladi* seasons, respectively).

The interaction between age of seedlings and plant population was found to be significant only during late *Thaladi* season (Table 27). At recommended plant population of 50 hills m^{-2}, planting of 25 days old seedlings gave significantly higher dry matter production (4059 kg ha^{-1}), followed by 32 days old seedlings (3169 kg ha^{-1}) and 39 days old seedlings (2994 kg ha^{-1}) which were on par. The lowest dry matter production was registered due to planting of 46 days old seedlings (1914 kg ha^{-1}). At 33 per cent higher plant population (66 hills m^{-2}), planting of 25 and 32 days old seedling were found to give higher dry matter production (4290 and 3766 kg ha^{-1}, respectively) which were on par and they were superior to that of 39 and 46 days old seedlings (2820 and 2281 kg ha^{-1}, respectively). Planting of 25,32 and 39 days old seedlings produced comparable dry matter at both the levels of plant population. But planting of 25 days old seedling gave the highest dry matter production (4290 kg ha^{-1}) at higher plant population of 66 hills m^{-2} as compared to planting of recommended plant population of 50 hills m^{-2} (4059 kg ha^{-1}).

The various interaction effects (PxN, AxN and AxPxN) did not affect the dry matter production during both the seasons. Pooled analysis of the dry matter production at maximum tillering stage revealed that the treatment as well as the seasonal influence had significant effect on dry matter production (Table 28). Planting of 25 days old young seedlings at recommended plant population (50 hills m^{-2}) and fertilizer nitrogen (100% N) gave the highest dry matter production (4281 kg ha^{-1}) and it was on par with that of seedlings of the same age at same level of fertilizer with higher plant population of 66 hills m^{-2}, followed by 32

Table 27. Effect of interaction between age of seedlings and plant population on dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at maximum tillering stage (late *Thaladi* season)

Plant population	Age of seedlings (days)			
	25	32	39	46
P_1: 50 hills m^{-2}	4059	3169	2994	1914
P_2: 66 hills m^{-2}	4290	3766	2820	2281
SEd	267			
CD (p=0.05%)	572**			

Table 28. Effect of season and treatments on the dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at maximum tillering stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	4278	4285	4281
$A_{25}P_{50}N_{75}$	3698	3832	3765
$A_{25}P_{66}N_{100}$	4282	3957	4119
$A_{25}P_{66}N_{75}$	3832	3576	3704
$A_{32}P_{50}N_{100}$	3619	3438	3529
$A_{32}P_{50}N_{75}$	3062	2900	2981
$A_{32}P_{66}N_{100}$	4146	4354	4250
$A_{32}P_{66}N_{75}$	3722	4226	3974
$A_{39}P_{50}N_{100}$	3145	2848	2994
$A_{39}P_{50}N_{75}$	3030	3146	3088
$A_{39}P_{66}N_{100}$	3568	3098	3333
$A_{39}P_{66}N_{75}$	3139	2540	2840
$A_{46}P_{50}N_{100}$	2526	2161	2344
$A_{46}P_{50}N_{75}$	2142	1667	1905
$A_{46}P_{66}N_{100}$	3170	2488	2829
$A_{46}P_{66}N_{75}$	2790	2074	2432
Mean	3384	3117	3273

	SEd	**CD (p = 0.05)**
Treatment	243	518
Season	64	176
Treatment x season	309	NS

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

days old seedling at higher plant population (66 hills m^{-2}) at both the levels of nitrogen (4119,4250 and 3974 kg ha^{-1}, respectively). The lowest dry matter production was obtained due to planting of 46 days old seedlings at recommended plant population and at both levels of nitrogen (2344 and 1905 kg ha^{-1} respectively). Among the seasons, late *Samba* was found to contribute for more dry matter production (3384 kg ha^{-1}) than late *Thaladi* season (3117 kg ha^{-1}). The overall dry matter production trend during both the seasons revealed that with ageing of the seedlings there was concomitant decline in dry matter production (Fig.11).

4.7.2. Panicle initiation stage (Table 29)

The dry matter production at panicle initiation stage was influenced by age of seedlings and nitrogen levels only during late *Thaladi* season and not in late *Samba* season. Planting of 32 days old seedlings produced the highest dry matter (8856 kg ha^{-1}), which was on par with that of 25 days old seedlings (8232 kg ha^{-1}) and this was comparable with that of 39 days old seedlings (7556 kg ha^{-1}). The lowest dry matter was produced due to planting of 46 days old seedlings (5335 kg ha^{-1}). Application of 100 per cent nitrogen gave higher dry matter production (7950 kg ha^{-1}) than 75 per cent nitrogen (7039 kg ha^{-1}). The plant population and other interaction effects (AxP, PxN, AxN and AxPxN) did not affect the dry matter production during panicle initiation stage in both the seasons.

The pooled analysis (Table 30) revealed that the dry matter production was not influenced by various treatments. However, it was influenced significantly by seasonal effect as well as the interaction between season and treatment. Among the seasons, late *Thaladi* season produced higher dry matter (7495 kg ha^{-1}) than late *Samba* season (6503 kg ha^{-1}). There was not much variation in dry matter production between the treatments during late *Samba* season. Whereas, during late *Thaladi* season the highest dry matter production was obtained due to planting of 25 days old young seedlings at higher plant population with 100 per cent nitrogen, followed by 32 days old seedlings at both the levels of population and nitrogen that were on par. The lowest dry matter production was obtained by planting 46 days old seedlings at higher plant population with 75 per cent nitrogen. Planting of 25 days old seedlings at both the levels of plant population with 100 per cent nitrogen and planting of 32 days old seedlings at both the levels of plant

Table 29. Effect of age of seedlings, plant population and nitrogen levels on dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at panicle initiation stage

Treatments	**Season**			
	Late *Samba*		**Late *Thaladi***	
Age of seedlings (A)				
A_1: 25 days old	6725		8232	
A_2: 32 days old	6758		8856	
A_3: 39 days old	6565		7556	
A_4: 46 days old	5965		5335	
SEd	**530**		**390**	
CD (p = 0.05)	**NS**		**836**	
Plant population (P)				
P_1: 50 hills m^{-2}	6696		7549	
P_2: 66 hills m^{-2}	6310		7440	
SEd	**375**		**280**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	6476		7950	
N_2: 75 per cent N	6531		7039	
SEd	**229**		**285**	
CD (p = 0.05)	**NS**		**605**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	750	NS	551	NS
Population x Nitrogen	440	NS	397	NS
Nitrogen x Age	458	NS	571	NS
Nitrogen x Population	324	NS	404	NS
Age x Nitrogen	622	NS	561	NS
Age x Population x Nitrogen	461	NS	483	NS

Table 30. Effect of season and treatments on dry matter production of *I.W.Ponni* rice variety at panicle initiation stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	6971	8345	7658
$A_{25}P_{50}N_{75}$	6457	7898	7177
$A_{25}P_{66}N_{100}$	6515	9568	8041
$A_{25}P_{66}N_{75}$	6956	7116	7036
$A_{32}P_{50}N_{100}$	6751	9461	8106
$A_{32}P_{50}N_{75}$	6943	8658	7801
$A_{32}P_{66}N_{100}$	6516	9358	7937
$A_{32}P_{66}N_{75}$	6822	7947	7385
$A_{39}P_{50}N_{100}$	6986	8024	7505
$A_{39}P_{50}N_{75}$	6731	6992	6861
$A_{39}P_{66}N_{100}$	6132	8162	7147
$A_{39}P_{66}N_{75}$	6413	7048	6731
$A_{46}P_{50}N_{100}$	6277	5213	5745
$A_{46}P_{50}N_{75}$	6456	5805	6121
$A_{46}P_{66}N_{100}$	5622	5471	5567
$A_{46}P_{66}N_{75}$	5466	4852	5159
Mean	6503	7495	6991

	SEd	CD (p = 0.05)
Treatment	910	NS
Season	264	732
Treatment x season	831	1662

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

population and nitrogen gave significantly higher dry matter production during late *Thaladi* season than during late *Samba* season. The other treatment combinations produced comparable dry matter yield during both the seasons.

4.7.3.Harvest stage (Table 31)

The age of seedlings, plant population, nitrogen levels and their interaction effects did not have any significant influence on the dry matter production at harvest stage during both seasons. The pooled analysis (Table 32) revealed that seasonal effect was significant with higher dry matter production during late *Thaladi* season (11110 kg ha^{-1}) than during late *Samba* season (7759 kg ha^{-1}).

4.8. Number of productive tillers $hill^{-1}$ (Table 33)

Age of seedlings had significant impact on the number of productive tillers $hill^{-1}$ only during late *Thaladi* season, with more number of productive tillers $hill^{-1}$ due to planting of 25,32 and 46 days old seedlings (6.98, 6.67 and 6.50, respectively) which were on par. But lesser number of productive tillers $hill^{-1}$ were observed due to planting of 39 days old seedlings (5.33). The plant population also had significant impact on the number of productive tillers $hill^{-1}$ but only during late *Samba* season, with more number of productive tillers $hill^{-1}$ in recommended plant population of 50 hills m^{-2} (6.53) than at 133 per cent higher plant population with 66 hills m^{-2} (5.52). The nitrogen levels as well as the other interaction effects did not affect the number of productive tillers $hill^{-1}$ significantly during both the seasons.

Pooled analysis (Table 34) revealed that neither the treatments nor the seasonal effect had influenced the number of productive tillers $hill^{-1}$. However the interaction of seasons with treatments had significantly influenced the number of productive tillers $hill^{-1}$ during late *Samba* season. Planting of 25 days old seedlings at recommended plant population with 100 per cent nitrogen gave higher number of productive tillers $hill^{-1}$. However, it was on par with 39 and 46 days old seedlings at 50 hills m^{-2} with 100 per cent nitrogen. Lesser number of productive tillers $hill^{-1}$ was recorded when 25 days old seedlings were planted at higher population with 100 per cent nitrogen. During late *Thaladi* season, 32 days old seedlings with 50 hills m^{-2} at 75 per cent nitrogen gave the highest number of productive tillers $hill^{-1}$ and it was on par with 25 days old seedlings at both the levels of plant population and

Table 31. Effect of age of seedlings, plant population and nitrogen levels on dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	8015	11195
A_2: 32 days old	7769	11455
A_3: 39 days old	7674	10582
A_4: 46 days old	7579	11205
SEd	**532**	**426**
CD (p = 0.05)	**NS**	**NS**
Plant population (P)		
P_1: 50 hills m^{-2}	7864	11158
P_2: 66 hills m^{-2}	7655	11061
SEd	**371**	**302**
CD (p = 0.05)	**NS**	**NS**
Nitrogen levels (N)		
N_1: 100 per cent N	7718	11053
N_2: 75 per cent N	7801	11166
SEd	**190**	**204**
CD (p = 0.05)	**NS**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	753	NS	609	NS
Population x Nitrogen	422	NS	364	NS
Nitrogen x Age	381	NS	408	NS
Nitrogen x Population	269	NS	289	NS
Age x Nitrogen	597	NS	515	NS
Age x Population x Nitrogen	417	NS	400	NS

Table 32. Effect of seasons and treatments on the dry matter production (kg ha^{-1}) of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	8443	11359	9901
$A_{25}P_{50}N_{75}$	7847	11233	9541
$A_{25}P_{66}N_{100}$	7558	11028	9293
$A_{25}P_{66}N_{75}$	8212	11160	9686
$A_{32}P_{50}N_{100}$	7690	11656	9673
$A_{32}P_{50}N_{75}$	7882	11188	9535
$A_{32}P_{66}N_{100}$	7548	11482	9515
$A_{32}P_{66}N_{75}$	7858	11496	9727
$A_{39}P_{50}N_{100}$	7947	10719	9333
$A_{39}P_{50}N_{75}$	7791	10563	9177
$A_{39}P_{66}N_{100}$	7212	10516	8864
$A_{39}P_{66}N_{75}$	7744	10530	9137
$A_{46}P_{50}N_{100}$	7595	10691	9143
$A_{46}P_{50}N_{75}$	7717	11857	9787
$A_{46}P_{66}N_{100}$	7748	10972	9360
$A_{46}P_{66}N_{75}$	7257	11301	9279
Mean	7758	11110	9434

	SEd	CD (p = 0.05)
Treatment	332	NS
Season	223	618
Treatment x season	775	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 33. Effect of age of seedlings, plant population and nitrogen levels on the number of productive tillers hill^{-1} of *I.W.Ponni* rice variety at harvest stage

Treatments	**Season**			
	Late *Samba*		**Late *Thaladi***	
Age of seedlings (A)				
A_1: 25 days old	5.85		6.98	
A_2: 32 days old	5.78		6.67	
A_3: 39 days old	6.18		5.33	
A_4: 46 days old	6.28		6.50	
SEd	**0.32**		**0.41**	
CD (p = 0.05)	**NS**		**0.89**	
Plant population (P)				
P_1: 50 hills m^{-2}	6.53		6.66	
P_2: 66 hills m^{-2}	5.52		6.08	
SEd	**0.23**		**0.29**	
CD (p = 0.05)	**0.49**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	6.04		6.35	
N_2: 75 per cent N	6.01		6.39	
SEd	**0.28**		**0.26**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.46	NS	0.59	NS
Population x Nitrogen	0.36	NS	0.39	NS
Nitrogen x Age	0.55	NS	0.52	NS
Nitrogen x Population	0.39	NS	0.37	NS
Age x Nitrogen	0.51	NS	0.56	NS
Age x Population x Nitrogen	0.45	NS	0.46	NS

Table 34. Effect of seasons and treatments on the number of productive tillers hill-1 of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	7.20	7.07	7.13
$A_{25}P_{50}N_{75}$	6.00	6.80	6.40
$A_{25}P_{66}N_{100}$	4.73	6.60	5.67
$A_{25}P_{66}N_{75}$	5.47	7.47	6.47
$A_{32}P_{50}N_{100}$	6.27	6.53	6.40
$A_{32}P_{50}N_{75}$	6.20	8.20	7.20
$A_{32}P_{66}N_{100}$	5.40	6.20	5.80
$A_{32}P_{66}N_{75}$	5.27	5.73	5.50
$A_{39}P_{50}N_{100}$	6.33	6.00	6.17
$A_{39}P_{50}N_{75}$	6.93	4.53	5.73
$A_{39}P_{66}N_{100}$	5.67	5.60	5.63
$A_{39}P_{66}N_{75}$	5.80	5.20	5.50
$A_{46}P_{50}N_{100}$	7.20	7.20	7.20
$A_{46}P_{50}N_{75}$	6.13	6.93	6.53
$A_{46}P_{66}N_{100}$	5.53	5.60	5.57
$A_{46}P_{66}N_{75}$	6.27	6.27	6.27
Mean	6.03	6.37	6.20

	SEd	CD (p = 0.05)
Treatment	0.78	NS
Season	0.14	NS
Treatment x season	0.75	1.51

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 35. Effect of age of seedlings, plant population and nitrogen levels on the number of unproductive tillers hill^{-1} of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	0.68		0.48	
A_2: 32 days old	0.75		0.45	
A_3: 39 days old	0.77		0.17	
A_4: 46 days old	0.65		0.25	
SEd	**0.19**		**0.07**	
CD (p = 0.05)	**NS**		**0.16**	
Plant population (P)				
P_1: 50 hills m^{-2}	0.70		0.38	
P_2: 66 hills m^{-2}	0.73		0.30	
SEd	**0.14**		**0.05**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	0.77		0.37	
N_2: 75 per cent N	0.66		0.31	
SEd	**0.14**		**0.09**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.27	NS	0.10	NS
Population x Nitrogen	0.19	NS	0.11	NS
Nitrogen x Age	0.29	NS	0.18	NS
Nitrogen x Population	0.20	NS	0.13	NS
Age x Nitrogen	0.27	NS	0.15	NS
Age x Population x Nitrogen	0.24	NS	0.14	NS

nitrogen. Lesser number of productive tillers $hill^{-1}$ were recorded in 39 days old seedlings at both population levels with 75 per cent nitrogen and in 46 days old seedlings with higher population and 100 per cent nitrogen.

4.9. **Number of panicles m^{-2}** (Table 36)

Age of seedlings had significant effect on the number of panicles m^{-2} only during late *Thaladi* season. Planting of young seedlings (25 and 32 days old) gave more number of panicles m^{-2} (374 and 347, respectively) than 39 and 46 days old seedlings (269 and 311, respectively). The plant population contributed significantly for the number of panicles m^{-2} during both the seasons, with more number of panicles m^{-2} at higher plant population of 66 hills m^{-2} (345) than recommended plant population of 50 hills m^{-2} (305).

The N levels and other interaction effects (AxP, AxN, PxN and AxPxN) did not influence the number of panicles m^{-2} during both the seasons. Pooled analysis (Table 37) revealed that neither the treatments nor the seasonal effect had any significant impact on the number of panicles m^{-2}. However, the interaction between season and treatment was significant. During late *Samba* season, planting of 46 days old seedlings at both the levels of plant population and nitrogen produced higher number of panicles m^{-2} and it was on par with that of 39 days old seedlings at higher population of 66 hills m^{-2} at both the levels of nitrogen. Lesser number of panicles m^{-2} were registered due to planting of 25 days old seedlings at 50 hills m^{-2} and with 75 per cent nitrogen. During late *Thaladi* season, planting of 25 days old seedlings at higher plant population and at both levels of nitrogen produced more number of panicles. Lesser number of panicles were produced by planting 39 days old seedlings at 50 hills m^{-2} at both the levels of N.

Planting of 25 days old seedlings with 66 hills m^{-2} at both levels of nitrogen and planting of 32 days old seedlings with 50 hills m^{-2} at 75 per cent nitrogen, resulted in significantly more number of panicles m^{-2} during late *Thaladi* season than late *Samba* season. Whereas 39 days old seedlings at both levels of population with 75 per cent nitrogen produced significantly more number of panicles m^{-2} during late *Samba* season than in late *Thaladi* season. The rest of the

Table 36. Effect of age of seedlings, plant population and nitrogen levels on the number of panicles m^{-2} of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	306		374	
A_2: 32 days old	305		347	
A_3: 39 days old	337		269	
A_4: 46 days old	344		311	
SEd	**20**		**24**	
CD (p = 0.05)	**NS**		**51**	
Plant population (P)				
P_1: 50 hills m^{-2}	303		305	
P_2: 66 hills m^{-2}	343		345	
SEd	**14**		**17**	
CD (p = 0.05)	**30**		**36**	
Nitrogen levels (N)				
N_1: 100 per cent N	323		329	
N_2: 75 per cent N	323		321	
SEd	**14**		**15**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	28	NS	34	NS
Population x Nitrogen	19	NS	23	NS
Nitrogen x Age	27	NS	30	NS
Nitrogen x Population	19	NS	22	NS
Age x Nitrogen	27	NS	32	NS
Age x Population x Nitrogen	23	NS	27	NS

Table 37. Effect of seasons and treatments on the number of panicle m^{-2} of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	335	339	337
$A_{25}P_{50}N_{75}$	268	312	290
$A_{25}P_{66}N_{100}$	288	412	350
$A_{25}P_{66}N_{75}$	334	434	384
$A_{32}P_{50}N_{100}$	292	308	300
$A_{32}P_{50}N_{75}$	279	377	328
$A_{32}P_{66}N_{100}$	328	372	350
$A_{32}P_{66}N_{75}$	319	331	325
$A_{39}P_{50}N_{100}$	293	275	284
$A_{39}P_{50}N_{75}$	326	208	267
$A_{39}P_{66}N_{100}$	361	315	338
$A_{39}P_{66}N_{75}$	366	276	321
$A_{46}P_{50}N_{100}$	338	320	329
$A_{46}P_{50}N_{75}$	294	302	298
$A_{46}P_{66}N_{100}$	348	292	320
$A_{46}P_{66}N_{75}$	397	327	362
Mean	323	325	324

	SEd	CD (p = 0.05)
Treatment	49	NS
Season	7	NS
Treatment x season	42	84

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

treatment combinations produced comparable number of panicles m^{-2} during both the seasons.

4.10. Panicle length (Table 38)

The panicle length was significantly influenced by the age of seedlings only during late *Samba* season. Planting of 25, 32 and 39 days old seedlings produced on par and longer panicles (21.4, 21.04 and 21,44 cm, respectively). Planting of 46 days old aged seedlings produced relatively shorter panicles (20.02 cm).

The plant population, nitrogen levels and the various interaction effects did not create any impact on the length of panicles during both the seasons. Pooled analysis (Table 39) revealed that the difference between the treatments were not significant. The seasonal influence was found to have significant effect on panicle length of *I W Ponni* rice variety, with longer panicles during late *Thaladi* season (23.69 cm) than in late *Samba* season (20.98 cm) (Fig. 16). The interaction effect between treatment and season was not significant.

4.11. Panicle weight (Table 40)

Age of seedlings as well as plant population were found to have significant impact on panicle weight only during the late *Samba* season and not in the late *Thaladi* season. Planting of 25 and 39 days old seedlings produced heavy panicles (2.00 and 1.94 g, respectively) which were on par and they were superior to that of 32 and 46 days old seedlings which produced light panicles (1.63 and 1.61 g, respectively) during late *Samba* season.

Planting of recommended plant population of 50 hills m^{-2} gave heavy panicles (1.88g) than the higher plant population of 66 hills m^{-2}, which produced light panicles (1.70g). The N levels and other interaction effects (AxP, AxN, PxN and AxPxN) did not affect panicle weight during both the seasons.

Pooled analysis (Table 41) revealed the significant impact of season on panicle weight, with more panicle weight in late *Thaladi* season (2.80 g) than at late *Samba* season (1.79 g). All the treatments gave relatively higher panicle weight during late *Thaladi* season than at late *Samba* season (Fig.17).

Table 38. Effect of age of seedlings, plant population and nitrogen levels on panicle length (cm) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	21.40		23.75	
A_2: 32 days old	21.04		24.05	
A_3: 39 days old	21.44		23.47	
A_4: 46 days old	20.02		23.50	
SEd	**0.40**		**0.37**	
CD (p = 0.05)	**0.86**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	21.22		23.73	
P_2: 66 hills m^{-2}	20.73		23.64	
SEd	**0.28**		**0.26**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	21.36		23.43	
N_2: 75 per cent N	20.60		23.95	
SEd	**0.43**		**0.37**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.57	NS	0.52	NS
Population x Nitrogen	0.52	NS	0.46	NS
Nitrogen x Age	0.87	NS	0.75	NS
Nitrogen x Population	0.61	NS	0.53	NS
Age x Nitrogen	0.73	NS	0.64	NS
Age x Population x Nitrogen	0.68	NS	0.60	NS

Table 39. Effect of seasons and treatments on panicle length (cm) of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	22.30	23.81	23.06
$A_{25}P_{50}N_{75}$	21.56	24.05	22.80
$A_{25}P_{66}N_{100}$	22.12	23.05	22.59
$A_{25}P_{66}N_{75}$	19.63	24.07	21.85
$A_{32}P_{50}N_{100}$	21.39	23.25	22.32
$A_{32}P_{50}N_{75}$	21.39	24.65	23.02
$A_{32}P_{66}N_{100}$	20.68	23.33	22.01
$A_{32}P_{66}N_{75}$	20.72	24.91	22.81
$A_{39}P_{50}N_{100}$	22.38	23.58	22.98
$A_{39}P_{50}N_{75}$	20.88	23.31	22.10
$A_{39}P_{66}N_{100}$	21.44	23.55	22.50
$A_{39}P_{66}N_{75}$	21.07	23.41	22.24
$A_{46}P_{50}N_{100}$	20.31	23.53	21.92
$A_{46}P_{50}N_{75}$	19.55	23.67	20.61
$A_{46}P_{66}N_{100}$	20.23	23.29	21.76
$A_{46}P_{66}N_{75}$	19.99	23.52	21.76
Mean	20.98	23.68	22.33

	SEd	CD (p = 0.05)
Treatment	0.75	NS
Season	0.18	0.52
Treatment x season	0.99	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 40. Effect of age of seedlings, plant population and nitrogen levels on panicle weight (g) of *I.W.Ponni* rice variety at harvest stage

Treatments	**Season**			
	Late *Samba*		**Late *Thaladi***	
Age of seedlings (A)				
A_1: 25 days old	2.00		2.84	
A_2: 32 days old	1.63		2.82	
A_3: 39 days old	1.94		2.83	
A_4: 46 days old	1.61		2.72	
SEd	**0.06**		**0.11**	
CD (p = 0.05)	**0.13**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	1.88		2.77	
P_2: 66 hills m^{-2}	1.70		2.84	
SEd	**0.04**		**0.08**	
CD (p = 0.05)	**0.10**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	1.79		2.77	
N_2: 75 per cent N	1.80		2.83	
SEd	**0.10**		**0.05**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.09	NS	0.16	NS
Population x Nitrogen	0.10	NS	0.09	NS
Nitrogen x Age	0.19	NS	0.09	NS
Nitrogen x Population	0.13	NS	0.07	NS
Age x Nitrogen	0.15	NS	0.13	NS
Age x Population x Nitrogen	0.14	NS	0.10	NS

Table 41. Effect of seasons and treatments on panicle weight (g) of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	2.02	2.84	2.43
$A_{25}P_{50}N_{75}$	2.15	2.83	2.49
$A_{25}P_{66}N_{100}$	2.02	2.77	2.39
$A_{25}P_{66}N_{75}$	1.80	2.92	2.36
$A_{32}P_{50}N_{100}$	1.80	2.51	2.16
$A_{32}P_{50}N_{75}$	1.66	2.98	2.32
$A_{32}P_{66}N_{100}$	1.54	2.96	2.25
$A_{32}P_{66}N_{75}$	1.53	2.82	2.18
$A_{39}P_{50}N_{100}$	2.17	2.76	2.47
$A_{39}P_{50}N_{75}$	2.04	2.85	2.44
$A_{39}P_{66}N_{100}$	1.66	2.87	2.27
$A_{39}P_{66}N_{75}$	1.86	2.86	2.36
$A_{46}P_{50}N_{100}$	1.51	2.75	2.13
$A_{46}P_{50}N_{75}$	1.71	2.65	2.18
$A_{46}P_{66}N_{100}$	1.58	2.72	2.15
$A_{46}P_{66}N_{75}$	1.64	2.77	2.20
Mean	1.79	2.80	230

	SEd	CD (p = 0.05)
Treatment	0.18	NS
Season	0.07	0.21
Treatment x season	0.20	NS

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

4.12. Number of filled grains panicle^{-1}, number of ill filled grains panicle^{-1} and sterility percentage (Table 42, 43, 44, 45, 46 and 47)

Age of seedlings did not influence the number of filled grains panicle^{-1} during both the seasons. However, plant population had significant impact only during late *Samba* season, with more number of filled grains panicle^{-1} at 50 hills m^{-2} (91.32) than at 66 hills m^{-2} (79.08). The nitrogen levels and other interaction effects (AxP, AxN, PxN and AxPxN) did not have any significant effect on number of filled grains panicle^{-1} during both the seasons.

The number of ill filled grains panicle^{-1} did not vary due to various treatments. In general, the ill filled grains panicle^{-1} were lesser during late *Samba* season (16.58 to 24.36 ill filled grains panicle^{-1}) and higher during late *Thaladi* season (33.96 to 41.67 ill filled grains panicle^{-1}) in various treatments.

The sterility percentage also did not vary significantly due to various treatments during both the seasons. The pooled analysis (Table 47) also revealed that the effect of treatments, seasonal effects and their interaction did not have any significant impact on sterility percentage. The sterility percentage ranged from 17.93 to 20.91 during late *Samba* season and from 16.65 to 20.08 during late *Thaladi* season.

4.13. Grain yield (Table 48)

The age of seedlings was found to affect the grain yield only during late *Thaladi* season and not in late *Samba* season. Planting of 32 days old seedlings gave the highest grain yield (5264 kg ha^{-1}) and it was on par with 25 days old seedlings (5136 kg ha^{-1}). This was followed by 46 days old seedlings, which gave 5048 kg ha^{-1}, and it was on par with that of 25 days old seedlings and 39 days old seedlings (4880 kg ha^{-1}). Planting of 32 days old seedlings was found to give 2.49 percent higher yield than that of 25 days old seedlings. Whereas, planting of 39 and 46 days old seedlings produced 4.98 per cent and 1.70 per cent lesser yield, respectively than that of 25 days old seedlings in late *Thaladi* season. During late *Samba* season, planting of 25,32,39 and 46 days old seedlings were found to produce 3341,3122, 3148 and 3033 kg ha^{-1}, respectively. Planting of 32,39 and 46

Table 42. Effect of age of seedlings, plant population and nitrogen levels on the number of filled grains panicle^{-1} of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	90.29		168.78	
A_2: 32 days old	78.03		166.83	
A_3: 39 days old	94.88		170.25	
A_4: 46 days old	77.60		160.15	
SEd	**8.06**		**9.65**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	91.32		163.69	
P_2: 66 hills m^{-2}	79.08		169.32	
SEd	**5.70**		**6.82**	
CD (p = 0.05)	**12.23**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	88.49		166.01	
N_2: 75 per cent N	81.90		166.99	
SEd	**5.83**		**3.97**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	11.40	NS	13.65	NS
Population x Nitrogen	8.15	NS	7.89	NS
Nitrogen x Age	11.65	NS	7.94	NS
Nitrogen x Population	8.24	NS	5.61	NS
Age x Nitrogen	11.53	NS	11.16	NS
Age x Population x Nitrogen	9.89	NS	8.15	NS

Table 43. Effect of seasons and treatments on the number of filled grains panicle^{-1} of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	106.20	168.63	137.42
$A_{25}P_{50}N_{75}$	88.17	167.33	127.75
$A_{25}P_{66}N_{100}$	91.47	167.93	129.70
$A_{25}P_{66}N_{75}$	75.33	171.27	123.30
$A_{32}P_{50}N_{100}$	85.20	141.20	113.20
$A_{32}P_{50}N_{75}$	82.93	173.73	128.33
$A_{32}P_{66}N_{100}$	77.23	181.47	129.35
$A_{32}P_{66}N_{75}$	66.73	170.93	118.83
$A_{39}P_{50}N_{100}$	114.33	167.20	140.77
$A_{39}P_{50}N_{75}$	99.07	169.20	134.13
$A_{39}P_{66}N_{100}$	77.00	172.27	124.63
$A_{39}P_{66}N_{75}$	89.13	172.33	130.73
$A_{46}P_{50}N_{100}$	72.73	168.40	120.57
$A_{46}P_{50}N_{75}$	81.93	153.80	117.87
$A_{46}P_{66}N_{100}$	83.80	161.00	122.40
$A_{46}P_{66}N_{75}$	71.93	157.40	114.67
Mean	85.20	166.51	125.85

	SEd	CD (p = 0.05)
Treatment	11.31	NS
Season	5.56	15.41
Treatment x season	15.92	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 44. Effect of age of seedlings, plant population and nitrogen levels on the number of ill filled grains panicle^{-1} of *I.W.Ponni* rice variety at harvest stage

Treatments	**Season**			
	Late *Samba*		**Late *Thaladi***	
Age of seedlings (A)				
A_1: 25 days old	24.62		33.41	
A_2: 32 days old	21.60		39.68	
A_3: 39 days old	17.95		39.60	
A_4: 46 days old	16.73		33.50	
SEd	**3.66**		**4.06**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	21.57		38.9	
P_2: 66 hills m^{-2}	18.88		34.17	
SEd	**2.59**		**2.07**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	22.77		35.28	
N_2: 75 per cent N	17.68		37.81	
SEd	**2.46**		**3.04**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	5.18	NS	5.73	NS
Population x Nitrogen	3.57	NS	4.18	NS
Nitrogen x Age	4.91	NS	6.09	NS
Nitrogen x Population	3.47	NS	4.30	NS
Age x Nitrogen	5.05	NS	5.91	NS
Age x Population x Nitrogen	4.25	NS	5.12	NS

Table 45. Effect of seasons and treatments on the number of ill filled grains panicle^{-1} of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	31.17	31.00	31.08
$A_{25}P_{50}N_{75}$	26.23	39.60	32.92
$A_{25}P_{66}N_{100}$	24.53	32.07	28.30
$A_{25}P_{66}N_{75}$	16.53	31.00	23.77
$A_{32}P_{50}N_{100}$	22.20	40.87	31.53
$A_{32}P_{50}N_{75}$	25.60	44.07	34.83
$A_{32}P_{66}N_{100}$	20.00	40.13	30.07
$A_{32}P_{66}N_{75}$	18.60	33.67	26.13
$A_{39}P_{50}N_{100}$	22.00	46.47	34.23
$A_{39}P_{50}N_{75}$	10.07	39.53	24.80
$A_{39}P_{66}N_{100}$	24.53	30.87	27.70
$A_{39}P_{66}N_{75}$	15.20	41.53	28.37
$A_{46}P_{50}N_{100}$	22.07	26.47	24.27
$A_{46}P_{50}N_{75}$	13.20	43.47	28.33
$A_{46}P_{66}N_{100}$	15.67	34.40	25.03
$A_{46}P_{66}N_{75}$	16.00	29.67	22.83
Mean	20.23	36.55	23.39

	SEd	CD (p = 0.05)
Treatment	6.26	NS
Season	2.36	6.56
Treatment x season	7.78	NS

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

Table 46. Effect of age of seedlings, plant population and nitrogen levels on spikelet sterility percentage of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	21.82		16.45	
A_2: 32 days old	22.26		19.28	
A_3: 39 days old	15.44		18.78	
A_4: 46 days old	17.55		17.12	
SEd	**3.93**		**1.74**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	19.22		19.17	
P_2: 66 hills m^{-2}	19.32		16.65	
SEd	**2.78**		**1.23**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	20.60		17.47	
N_2: 75 per cent N	17.93		18.35	
SEd	**1.96**		**1.20**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	5.56	NS	2.45	NS
Population x Nitrogen	3.40	NS	1.72	NS
Nitrogen x Age	3.92	NS	2.41	NS
Nitrogen x Population	2.77	NS	1.70	NS
Age x Nitrogen	4.81	NS	2.43	NS
Age x Population x Nitrogen	3.73	NS	2.07	NS

Table 47. Effect of seasons and treatments on spikelet sterility percentage of *I.W.Ponni* rice variety at harvest stage (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	23.12	15.43	19.28
$A_{25}P_{50}N_{75}$	23.38	19.13	21.26
$A_{25}P_{66}N_{100}$	21.61	15.95	18.78
$A_{25}P_{66}N_{75}$	19.19	15.30	17.24
$A_{32}P_{50}N_{100}$	21.08	22.51	21.80
$A_{32}P_{50}N_{75}$	24.31	20.32	22.32
$A_{32}P_{66}N_{100}$	21.87	18.14	20.00
$A_{32}P_{66}N_{75}$	21.77	16.14	18.96
$A_{39}P_{50}N_{100}$	15.67	21.87	18.77
$A_{39}P_{50}N_{75}$	9.19	18.98	14.09
$A_{39}P_{66}N_{100}$	22.26	15.04	18.65
$A_{39}P_{66}N_{75}$	14.65	19.24	16.95
$A_{46}P_{50}N_{100}$	23.79	13.26	18.53
$A_{46}P_{50}N_{75}$	13.22	21.87	17.55
$A_{46}P_{66}N_{100}$	15.43	17.55	16.49
$A_{46}P_{66}N_{75}$	17.74	15.81	16.78
Mean	19.27	17.99	18.59

	SEd	**CD (p = 0.05)**
Treatment	4.31	NS
NS Season	2.31	NS
Treatment x season	5.35	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 48. Effect of age of seedlings, plant population and nitrogen levels on grain yield (kg ha^{-1}) of *I.W.Ponni* rice variety

Treatments	Season	
	Late *Samba*	Late *Thaladi*
Age of seedlings (A)		
A_1: 25 days old	3341	5136
A_2: 32 days old	3122	5264
A_3: 39 days old	3148	4880
A_4: 46 days old	3033	5048
SEd	**276**	**95**
CD (p = 0.05)	**NS**	**204**
Plant population (P)		
P_1: 50 hills m^{-2}	3304	5152
P_2: 66 hills m^{-2}	3018	5012
SEd	**195**	**67**
CD (p = 0.05)	**NS**	**NS**
Nitrogen levels (N)		
N_1: 100 per cent N	3114	5048
N_2: 75 per cent N	3207	5116
SEd	**156**	**71**
CD (p = 0.05)	**NS**	**NS**

Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	391	NS	134	NS
Population x Nitrogen	250	NS	98	NS
Nitrogen x Age	311	NS	143	NS
Nitrogen x Population	220	NS	101	NS
Age x Nitrogen	353	NS	139	NS
Age x Population x Nitrogen	284	NS	120	NS

days old seedlings were found to give 6.57, 5.79 and 9.21 per cent reduced yield as compared to that of 25 days old seedlings, during late *Samba* season.

The plant population did not affect the grain yield significantly during both the seasons. Recommended plant population of 50 hills m^{-2} at 20x10 cm produced 3304 and 5152 kg ha^{-1}, respectively during late *Samba* and late *Thaladi* seasons. Planting with 133 per cent higher plant population (33% extra seedlings) produced 3018 and 5012 kg ha^{-1} respectively during late *Samba* and late *Thaladi* seasons. During both the seasons, in fact there was slight reduction in grain yield due to increase in plant population to 66 hills m^{-2} (8.5 percent and 2.7 per cent reduced yield, respectively as compared to 50 hills m^{-2}).

The nitrogen levels did not influence the grain yield significantly during both the seasons. The currently recommended dose of 100 per cent nitrogen (150 kg N ha^{-1}) produced 3114 and 5048 kg ha^{-1} grain yield, respectively during late *Samba* and late *Thaladi* seasons. Application of 75 per cent of recommended dose of nitrogen (112.5 kg ha^{-1}) produced 3207 and 5116 kg ha^{-1}, respectively during late *Samba* and late *Thaladi* seasons. In fact there was slight increase in the yield due to 25 per cent reduction in nitrogen (2.99 per cent and 1.35 per cent increased yield at 75 per cent nitrogen during late *Samba* and late *Thaladi* seasons, respectively as compared to 100 per cent nitrogen).

The various interaction effects (AxN, PxN, AxN and AxPxN) did not have any significant impact on grain yield during both the seasons.

The pooled analysis (Table 49) of the grain yield of the two seasons revealed that the treatmental effect was not significant. Only the seasonal effect was significant in influencing the grain yield (Fig.18). The interaction between season and treatment was also not significant. Among the two seasons, the grain yield was very high during late *Thaladi* season (5082 kg ha^{-1}) and it was very low during late *Samba* season (3161 kg ha^{-1}). The yield increase in late *Thaladi* due to favourable seasonal effect was 60.77 per cent over late *Samba*.

4.14. **Straw yield** (Table 50)

The straw yield did not vary significantly due to planting of aged seedlings, increasing of the plant population and decreasing of the N level during both the

Table 49. Effect of seasons and treatments on grain yield (kg ha^{-1}) of *I.W.Ponni* rice variety (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	3523	5368	4445
$A_{25}P_{50}N_{75}$	3367	5554	4360
$A_{25}P_{66}N_{100}$	3029	4897	3963
$A_{25}P_{66}N_{75}$	3445	4925	4185
$A_{32}P_{50}N_{100}$	3003	5191	4097
$A_{32}P_{50}N_{75}$	3123	5322	4223
$A_{32}P_{66}N_{100}$	2990	5322	4156
$A_{32}P_{66}N_{75}$	3370	5220	4295
$A_{39}P_{50}N_{100}$	3400	4944	4172
$A_{39}P_{50}N_{75}$	3276	4784	4030
$A_{39}P_{66}N_{100}$	2769	4816	3793
$A_{39}P_{66}N_{75}$	3146	4976	4061
$A_{46}P_{50}N_{100}$	3471	4979	4225
$A_{46}P_{50}N_{75}$	3267	5271	4269
$A_{46}P_{66}N_{100}$	2730	4866	3798
$A_{46}P_{66}N_{75}$	2665	5077	3871
Mean	3161	5082	4121

	SEd	CD (p = 0.05)
Treatment	211	NS
Season	138	381
Treatment x season	377	NS

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

Table 50. Effect of age of seedlings, plant population and nitrogen levels on straw yield (kg ha^{-1}) of *I.W.Ponni* rice variety

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	4674		6060	
A_2: 32 days old	4648		6192	
A_3: 39 days old	4526		5702	
A_4: 46 days old	4400		6157	
SEd	**323**		**378**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	4560		6007	
P_2: 66 hills m^{-2}	4564		6049	
SEd	**228**		**267**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	4530		6005	
N_2: 75 per cent N	4594		6050	
SEd	**100**		**153**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	456	NS	534	NS
Population x Nitrogen	249	NS	308	NS
Nitrogen x Age	199	NS	305	NS
Nitrogen x Population	141	NS	216	NS
Age x Nitrogen	352	NS	435	NS
Age x Population x Nitrogen	235	NS	316	NS

seasons. Similarly, the various interaction effects also did not have any significant effect on straw yield.

Pooled analysis (Table 51) also confirmed that the treatments did not have significant effect on straw yield. The seasonal effect was very significant in influencing the straw yield (Fig.19). Late *Thaladi* season produced more straw (6028 kg ha^{-1}) than late *Samba* season (4562 kg ha^{-1}). The interaction between season and treatment was also not significant.

4.15. Harvest index (Table 52)

The harvest index did not vary significantly due to age of seedlings, N levels and plant population and their interaction effects during both the seasons. The harvest index ranged from 0.40 to 0.42 during late *Samba* season and from 0.45 to 0.46 during late *Samba* season.

4.16. Test weight (1000 grain weight) (Table 53)

The test weight was not changed significantly due to age of seedlings, plant population, nitrogen levels and their interaction effects during both the seasons. However, pooled analysis (Table 54) revealed significant variation between the treatments in respect of test weight. Planting of 46 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen, followed by 32 days old seedlings at 66 hills m^{-2} with 100 per cent nitrogen and 25 days old seedlings at 50 hills m^{-2} with 100 per cent nitrogen were found to give higher 1000 grain weight and were all on par. Lesser 1000 grain weight was recorded when 46 days old seedlings were planted at 66 hills m^{-2} with 75 per cent nitrogen and with 25 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen.

4.17. Nitrogen, Phosphorus and Potassium uptake by plants at harvest stage (Table 55, 56 and 57)

The N, P and K uptake were not affected either by age of seedlings or plant population or by nitrogen levels or by their interaction effects. The plant nitrogen uptake ranged from 113.14 to 148.29 kg ha^{-1} for various treatments during late *Thaladi* season and from 76.41 to 109.77 kg ha^{-1} in late *Samba* season. The plant

Table 51. Effect of seasons and treatments on straw yield (kg ha^{-1}) of *I.W.Ponni* rice variety (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	4920	5991	5456
$A_{25}P_{50}N_{75}$	4480	5880	5180
$A_{25}P_{66}N_{100}$	4528	6131	5330
$A_{25}P_{66}N_{75}$	4767	6236	5501
$A_{32}P_{50}N_{100}$	4687	6465	5576
$A_{32}P_{50}N_{75}$	4758	5866	5312
$A_{32}P_{66}N_{100}$	4558	6160	5359
$A_{32}P_{66}N_{75}$	4588	6276	5432
$A_{39}P_{50}N_{100}$	4548	5775	5161
$A_{39}P_{50}N_{75}$	4515	5779	5147
$A_{39}P_{66}N_{100}$	4443	5700	5072
$A_{39}P_{66}N_{75}$	4598	5554	5076
$A_{46}P_{50}N_{100}$	4123	5712	4918
$A_{46}P_{50}N_{75}$	4450	6586	5518
$A_{46}P_{66}N_{100}$	4433	6106	5270
$A_{46}P_{66}N_{75}$	4592	6224	5408
Mean	4562	6028	5295

	SEd	CD (p = 0.05)
Treatment	217	NS
Season	180	500
Treatment x season	549	NS

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

Table 52. Effect of age of seedlings, plant population and nitrogen levels on harvest index of *I.W.Ponni* rice variety

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	0.42		0.46	
A_2: 32 days old	0.40		0.46	
A_3: 39 days old	0.41		0.46	
A_4: 46 days old	0.40		0.45	
SEd	**0.02**		**0.01**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	0.42		0.46	
P_2: 66 hills m^{-2}	0.39		0.45	
SEd	**0.01**		**0.01**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	0.40		0.46	
N_2: 75 per cent N	0.41		0.46	
SEd	**0.01**		**0.004**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.02	NS	0.02	NS
Population x Nitrogen	0.02	NS	0.01	NS
Nitrogen x Age	0.03	NS	0.01	NS
Nitrogen x Population	0.02	NS	0.01	NS
Age x Nitrogen	0.03	NS	0.02	NS
Age x Population x Nitrogen	0.02	NS	0.01	NS

Table 53. Effect of age of seedlings, plant population and nitrogen levels on 1000 grain weight (g) of *I.W.Ponni* rice variety

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	17.23		17.37	
A_2: 32 days old	17.80		17.78	
A_3: 39 days old	17.37		17.66	
A_4: 46 days old	17.25		17.68	
SEd	**0.49**		**0.29**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	17.45		17.70	
P_2: 66 hills m^{-2}	17.37		17.54	
SEd	**0.35**		**0.20**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	17.43		17.61	
N_2: 75 per cent N	17.40		17.63	
SEd	**0.24**		**0.22**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.70	NS	0.41	NS
Population x Nitrogen	0.42	NS	0.30	NS
Nitrogen x Age	0.48	NS	0.44	NS
Nitrogen x Population	0.34	NS	0.31	NS
Age x Nitrogen	0.60	NS	0.43	NS
Age x Population x Nitrogen	0.46	NS	0.37	NS

Table 54. Effect of seasons and treatments on 1000 grain weight (g) of *I.W.Ponni* rice variety (Pooled analysis)

Treatments	Late *Samba*	Late *Thaladi*	Mean
$A_{25}P_{50}N_{100}$	18.09	17.48	17.79
$A_{25}P_{50}N_{75}$	16.62	17.46	17.04
$A_{25}P_{66}N_{100}$	17.35	16.94	17.15
$A_{25}P_{66}N_{75}$	16.87	17.59	17.23
$A_{32}P_{50}N_{100}$	17.19	17.73	17.46
$A_{32}P_{50}N_{75}$	17.22	17.28	17.25
$A_{32}P_{66}N_{100}$	18.47	18.36	18.42
$A_{32}P_{66}N_{75}$	18.31	17.74	18.02
$A_{39}P_{50}N_{100}$	17.27	18.07	17.67
$A_{39}P_{50}N_{75}$	18.04	17.68	17.86
$A_{39}P_{66}N_{100}$	17.16	17.64	17.40
$A_{39}P_{66}N_{75}$	17.01	17.23	17.12
$A_{46}P_{50}N_{100}$	16.73	17.29	17.01
$A_{46}P_{50}N_{75}$	18.45	18.63	18.54
$A_{46}P_{66}N_{100}$	17.16	17.39	17.28
$A_{46}P_{66}N_{75}$	16.66	17.42	17.04
Mean	17.41	17.62	17.52

	SEd	CD (p = 0.05)
Treatment	0.35	0.75
Season	0.17	NS
Treatment x season	0.74	NS

A_{25} – 25 days old seedlings; A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings; A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}; P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N; N_{75} – 75% recommended N

Table 55. Effect of age of seedlings, plant population and nitrogen levels on plant nitrogen uptake (kg ha^{-1}) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	101.31		122.82	
A_2: 32 days old	98.78		120.93	
A_3: 39 days old	89.19		135.07	
A_4: 46 days old	92.88		137.34	
SEd	**9.13**		**10.77**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	100.16		130.52	
P_2: 66 hills m^{-2}	90.91		127.57	
SEd	**6.46**		**7.61**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	94.26		127.97	
N_2: 75 per cent N	96.82		130.11	
SEd	**4.10**		**5.14**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	12.91	NS	15.23	NS
Population x Nitrogen	7.65	NS	9.19	NS
Nitrogen x Age	8.20	NS	10.28	NS
Nitrogen x Population	5.80	NS	7.27	NS
Age x Nitrogen	10.82	NS	12.99	NS
Age x Population x Nitrogen	8.12	NS	9.93	NS

Table 56. Effect of age of seedlings, plant population and nitrogen levels on plant phosphorus uptake (kg ha^{-1}) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	10.16		11.21	
A_2: 32 days old	9.69		10.88	
A_3: 39 days old	9.72		11.60	
A_4: 46 days old	9.55		12.39	
SEd	**0.41**		**0.57**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	9.91		11.51	
P_2: 66 hills m^{-2}	9.64		11.53	
SEd	**0.29**		**0.40**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	9.76		11.50	
N_2: 75 per cent N	9.79		11.54	
SEd	**0.22**		**0.38**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	0.58	NS	0.81	NS
Population x Nitrogen	0.36	NS	0.55	NS
Nitrogen x Age	0.44	NS	0.75	NS
Nitrogen x Population	0.31	NS	0.53	NS
Age x Nitrogen	0.51	NS	0.78	NS
Age x Population x Nitrogen	0.41	NS	0.65	NS

Table 57. Effect of age of seedlings, plant population and nitrogen levels on plant potassium uptake (kg ha^{-1}) of *I.W.Ponni* rice variety at harvest stage

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	111.09		167.32	
A_2: 32 days old	113.50		162.25	
A_3: 39 days old	103.23		170.11	
A_4: 46 days old	105.43		160.20	
SEd	**8.47**		**10.45**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	110.50		167.00	
P_2: 66 hills m^{-2}	106.14		162.94	
SEd	**5.99**		**7.39**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	105.96		162.21	
N_2: 75 per cent N	110.69		167.73	
SEd	**5.38**		**6.35**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	11.98	NS	14.77	NS
Population x Nitrogen	8.05	NS	9.74	NS
Nitrogen x Age	10.76	NS	12.69	NS
Nitrogen x Population	7.61	NS	8.97	NS
Age x Nitrogen	11.39	NS	13.77	NS
Age x Population x Nitrogen	9.45	NS	11.29	NS

phosphorus uptake ranged from 9.14 to 10.30 kg ha^{-1} in late *Samba* season and from 10.73 to 13.85 kg ha^{-1} in late *Thaladi* season. The plant K uptake ranged from 99.83 to 122.10 kg ha^{-1} in late *Samba* season and from 148.09 to 188.38 kg ha^{-1} in late *Thaladi* season.

4.18. Post – harvest available Nitrogen, Phosphorus and Potassium in soil (Table 58, 59 and 60)

Analysis of post harvest soil available N, P and K revealed that there was no significant difference in available N, P and K due to various treatments and their interaction effects. The available nitrogen ranged from 146.17 to 168.10 kg ha^{-1} during late *Samba* season and from 138.97 to 158.57 kg ha^{-1} in late *Thaladi* season. The available phosphorus ranged from 15.23 to 19.34 kg ha^{-1} in late *Samba* season and from 10.52 to 18.83 in late *Thaladi* season. The available potassium ranged from 150.00 to 175.33 kg ha^{-1} in late *Samba* season and from144.33 to 159.00 kg ha^{-1} in late *Thaladi* season.

4.19. Economics (Table 61)

The gross return was the highest due to planting of 25 days old seedlings at recommended plant population of 50 hills m^{-2} with recommended dose of 150 kg N ha^{-1} (Rs.27049 ha^{-1}), in late *Samba* season. In late *Thaladi* season, the same set of treatments (25 days old seedlings at 50 hills m^{-2}) but with 75 per cent dose of nitrogen (112.50 kg N ha^{-1}) gave the highest gross return (Rs.41517 ha^{-1}). Similarly, the net return was also the highest due to planting of 25 days old seedlings at recommended plant population of 50 hills m^{-2} with 100 per cent nitrogen during late *Samba* season (Rs.8899 ha^{-1}). In late *Thaladi* season, 25 days old seedlings with 50 hills m^{-2} at 75 per cent nitrogen gave the highest net return (Rs.21410 ha^{-1}). The benefit cost ratio was the highest due to planting of 25 days old seedlings with 50 hills m^{-2} at 100 per cent nitrogen (1.49) in late *Samba* season and it was same due to planting of 25 days old seedlings but with 66 hills m^{-2} at 75 per cent nitrogen (1.49) in late *Samba* season. In late *Thaladi* season, the highest benefit cost ratio was obtained by planting 25 days old seedlings with 50 hills m^{-2} at 75 per cent nitrogen (2.06).

Table 58. Effect of age of seedlings, plant population and nitrogen levels on post harvest available nitrogen in soil (kg ha^{-1})

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	151.08		153.59	
A_2: 32 days old	152.56		150.98	
A_3: 39 days old	158.57		146.64	
A_4: 46 days old	154.86		149.61	
SEd	**8.68**		**7.22**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	153.77		151.13	
P_2: 66 hills m^{-2}	154.76		149.28	
SEd	**6.13**		**5.11**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	161.50		153.43	
N_2: 75 per cent N	148.22		146.98	
SEd	**5.27**		**5.17**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	12.27	NS	10.22	NS
Population x Nitrogen	8.09	NS	7.27	NS
Nitrogen x Age	10.53	NS	10.35	NS
Nitrogen x Population	7.45	NS	7.32	NS
Age x Nitrogen	11.43	NS	10.28	NS
Age x Population x Nitrogen	9.37	NS	8.80	NS

Table 59. Effect of age of seedlings, plant population and nitrogen levels on post harvest available phosphorus in soil (kg ha^{-1})

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	16.62		14.48	
A_2: 32 days old	16.74		14.79	
A_3: 39 days old	17.86		17.61	
A_4: 46 days old	18.22		14.84	
SEd	**1.35**		**1.50**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	17.01		13.84	
P_2: 66 hills m^{-2}	17.71		15.51	
SEd	**0.95**		**1.06**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	17.53		14.69	
N_2: 75 per cent N	17.19		14.67	
SEd	**0.89**		**1.17**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	1.90	NS	2.13	NS
Population x Nitrogen	1.30	NS	1.58	NS
Nitrogen x Age	1.78	NS	2.35	NS
Nitrogen x Population	1.26	NS	1.66	NS
Age x Nitrogen	1.84	NS	2.24	NS
Age x Population x Nitrogen	1.55	NS	1.96	NS

Table 60. Effect of age of seedlings, plant population and nitrogen levels on post harvest available potassium in soil (kg ha^{-1})

Treatments	Season			
	Late *Samba*		Late *Thaladi*	
Age of seedlings (A)				
A_1: 25 days old	160.92		152.33	
A_2: 32 days old	159.50		150.17	
A_3: 39 days old	159.00		153.25	
A_4: 46 days old	162.25		154.50	
SEd	**6.65**		**6.90**	
CD (p = 0.05)	**NS**		**NS**	
Plant population (P)				
P_1: 50 hills m^{-2}	162.75		152.50	
P_2: 66 hills m^{-2}	158.08		152.63	
SEd	**4.70**		**4.88**	
CD (p = 0.05)	**NS**		**NS**	
Nitrogen levels (N)				
N_1: 100 per cent N	162.46		154.38	
N_2: 75 per cent N	158.38		150.75	
SEd	**5.25**		**6.02**	
CD (p = 0.05)	**NS**		**NS**	
Interactions	**SEd**	**CD (p=0.05)**	**SEd**	**CD (p=0.05)**
Age x Population	9.41	NS	9.76	NS
Population x Nitrogen	7.05	NS	7.75	NS
Nitrogen x Age	10.50	NS	12.04	NS
Nitrogen x Population	7.42	NS	8.51	NS
Age x Nitrogen	9.97	NS	10.96	NS
Age x Population x Nitrogen	8.73	NS	9.81	NS

Table 61. Effect of age of seedlings, plant population and nitrogen levels on cost of cultivation, gross return, net return and benefit cost ratio in *I.W.Ponni* rice variety

Treatments	Cost of cultivation (Rs)		Gross return (Rs)		Net return (Rs)		Benefit cost ratio	
	late *Samba*	late *Thaladi*	late *Samba*	late *Thaladi*	late *Samba*	late *Thaladi*	late *Samba*	late *Thaladi*
$A_{25}P_{50}N_{100}$	18151	20254	27049	40312	8899	20058	1.49	1.99
$A_{25}P_{50}N_{75}$	17479	20108	25719	41517	8104	21410	1.46	2.06
$A_{25}P_{66}N_{100}$	17588	19717	23435	37174	5848	17457	1.33	1.89
$A_{25}P_{66}N_{75}$	17700	19391	26424	37429	8721	18039	1.49	1.93
$A_{32}P_{50}N_{100}$	17558	20052	23353	39385	5795	19333	1.33	1.96
$A_{32}P_{50}N_{75}$	17336	19843	24216	39922	6880	20079	1.40	2.01
$A_{32}P_{66}N_{100}$	17543	20202	23186	40098	5643	19897	1.32	1.98
$A_{32}P_{66}N_{75}$	17618	19727	25804	39470	8186	19743	1.46	2.00
$A_{39}P_{50}N_{100}$	18011	19771	25985	37282	7974	17511	1.44	1.89
$A_{39}P_{50}N_{75}$	17511	19230	25117	36190	7606	16960	1.43	1.88
$A_{39}P_{66}N_{100}$	17291	19625	21606	36361	4315	16737	1.25	1.85
$A_{39}P_{66}N_{75}$	17363	19449	24277	37368	6915	17919	1.40	1.92
$A_{46}P_{50}N_{100}$	18091	19811	26215	37484	8124	17673	1.45	1.89
$A_{46}P_{50}N_{75}$	17501	19785	25016	40005	7516	20220	1.43	2.02
$A_{46}P_{66}N_{100}$	17247	19682	21333	36947	4086	17265	1.24	1.88
$A_{46}P_{66}N_{75}$	16814	19564	20984	38486	4170	18922	1.25	1.97
A_1: 25 days	17764	19867	25657	39108	7893	19241	1.44	1.97
A_2: 32 days	17514	19956	24140	39719	6626	19673	1.38	1.99
A_3: 39 days	17363	19519	24221	36800	6859	17282	1.40	1.89
A_4: 46 days	17413	19710	23387	38231	5974	18520	1.34	1.94
P_1: 50 hills m^{-2}	17767	19857	25334	39012	7567	19155	1.43	1.96
P_2: 66 hills m^{-2}	17396	19669	23369	37917	5973	18247	1.34	1.93
N_1: 100 % N	17685	19183	24018	38131	6333	18949	1.36	1.99
N_2: 75 % N	16983	18892	24692	38623	7709	19731	1.45	2.04
Mean	**17513**	**19763**	**24351**	**38465**	**6838**	**18701**	**1.39**	**1.95**

In all the treatments, the gross return was higher in late *Thaladi* season than in late *Samba* season. Similar trend was observed in case of net return and benefit cost ratio also. The gross return ranged from Rs.20984 to Rs.27049 ha^{-1} during late *Samba* season and from Rs.36190 to Rs.41517 ha^{-1}during late *Thaladi* season for various treatments. Similarly, the net returns ranged from Rs.4086 to Rs.8899 ha^{-1} during late *Samba* season and from Rs.16737 to Rs.21410 ha^{-1} during late *Thaladi* season for various treatments. The benefit cost ratio also ranged from 1.24 to 1.49 in late *Samba* season and from 1.85 to 2.06 in late *Thaladi* season.

During late *Samba* season the treatment combination of planting 25 days old seedlings at recommended plant population of 50 hills m^{-2} with recommended dose of 100 per cent nitrogen (150 kg N ha^{-1} + common dose of P and K, at 50:50 kg ha^{-1}) gave the highest gross return (Rs.27049 ha^{-1}) net return (Rs.8899 ha^{-1}) and benefit cost ratio (1.49). During late *Thaladi* season, the treatment combination of planting 25 days old seedlings at recommended plant population of 50 hills m^{-2} with 75 per cent recommended dose of nitrogen (112.5 kg N ha^{-1}+ common dose of P and K at 50: 50 kg ha^{-1}) gave the highest gross return (Rs.41517 ha^{-1}), net return (Rs.21410 ha^{-1}) and benefit cost ratio (2.06).

As far as the impact of plant population was concerned, irrespective of age of seedlings and nitrogen levels, planting with recommended plant population of 50 hills m^{-2} at 20x10 cm gave the highest gross return (Rs.25334 and Rs.39012 ha^{-1}), net return (Rs.7567 and Rs.19155 ha^{-1}) and benefit cost ratio (1.43 and 1.96) during late *Samba* and late *Thaladi* seasons, respectively.

Regarding the nitrogen levels and its economics, application of 75 per cent nitrogen (112.5 kg ha^{-1}), irrespective of plant population and age of seedlings gave the highest gross return (Rs.24692 ha^{-1}), net return (Rs.7709 ha^{-1}) and benefit cost ratio (1.45) during late *Samba* season. Similar trend was observed for late *Thaladi* season also with the highest gross return (Rs.38623 ha^{-1}), net return (Rs.19731 ha^{-1}) and benefit cost ratio (2.04) with 75 per cent nitrogen.

4.20. **Correlation studies** (Table 62)

The correlation studies between various growth parameters and grain yield revealed that the dry matter production at panicle initiation and harvest stage, the

Table 62. Correlation of various growth and yield parameters on grain yield of *I.W.Ponni* rice variety

Parameter	Late *Samba*	Late *Thaladi*
Plant height at maximum tillering stage	0.1940	0.1106
Plant height at panicle initiation stage	0.1503	0.2129
Plant height at harvest stage	0.2015	0.0380
Number of leaves tiller^{-1} at maximum tillering stage	- 0.1532	-0.1871
Number of leaves tiller^{-1} at panicle initiation stage	0.0291	-0.0688
Leaf area index at maximum tillering stage	- 0.1855	0.1039
Leaf area index at panicle initiation stage	- 0.0731	- 0.0425
Number of tillers hill^{-1} at maximum tillering stage	0.0631	0.0035
Number of tillers hill^{-1} at panicle initiation stage	0.1838	0.2403
Number of tillers hill^{-1} at harvest stage	- 0.0920	0.2767
Dry matter production at maximum tillering stage	0.0135	0.0850
Dry matter production at panicle initiation stage	0.8211**	0.0056
Dry matter production at harvest stage	0.9886**	0.6429**
Days to 50 % flowering	- 0.1909	- 0.2589
Number of productive tillers hill^{-1}	- 0.0406	0.2454
Number of unproductive tillers hill^{-1}	- 0.2133	0.0709
Number of panicles m^{-2}	- 0.3069	0.0789
Panicle weight	0.2067	0.2191
Panicle length	- 0.0441	0.3215*
Number of filled grains panicle $^{-1}$	0.0988	0.1898
Number of ill filled grains panicle $^{-1}$	0.0882	0.0971
Straw yield	0.3978**	0.3717**
Harvest index	0.7896**	0.1334
1000 grain weight	0.2432	0.0533

straw yield at harvest stage and the harvest index were found to influence the grain yield positively and significantly during late *Samba* season. However, during late *Thaladi* season, the dry matter production at harvest stage, panicle length and straw yields were found to influence the grain yield positively as well as significantly.

DISCUSSION

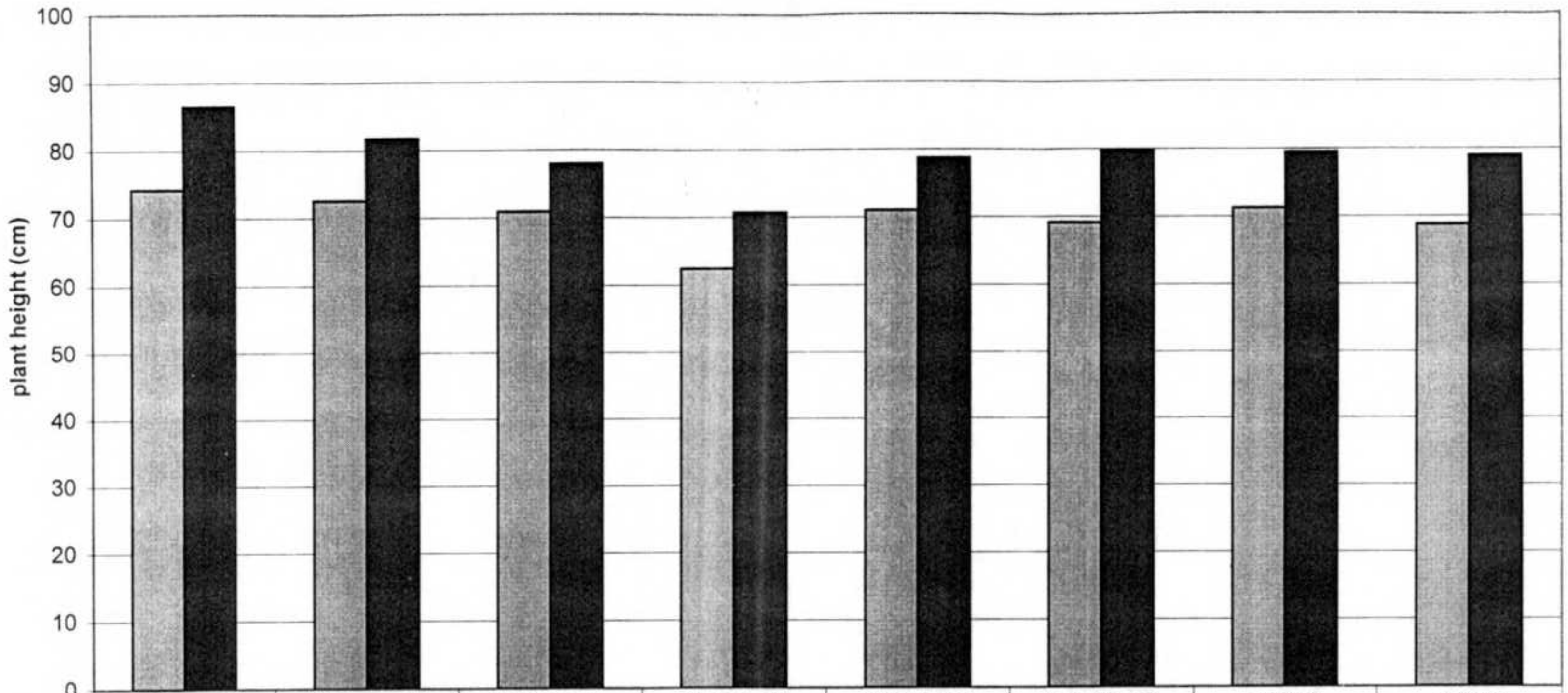
CHAPTER 5

DISCUSSION

Two field experiments (one in late *Samba* and another in late *Thaladi* seasons) were conducted at PAJANCOA & RI, Karaikal to study the "Agronomic management of aged seedlings of Improved *White Ponni* rice variety for Karaikal region" with 16 treatment combinations involving four ages of seedlings (25, 32, 39 and 46 days old) and two population levels (50 and 66 hill m^{-2}) in the main plots and two nitrogen levels (100 and 75 per cent recommended dose of N) in sub-plots, replicated thrice. The results of the two experiments are discussed in this chapter.

5.1. **Plant height** (Fig.3, 4 and 5)

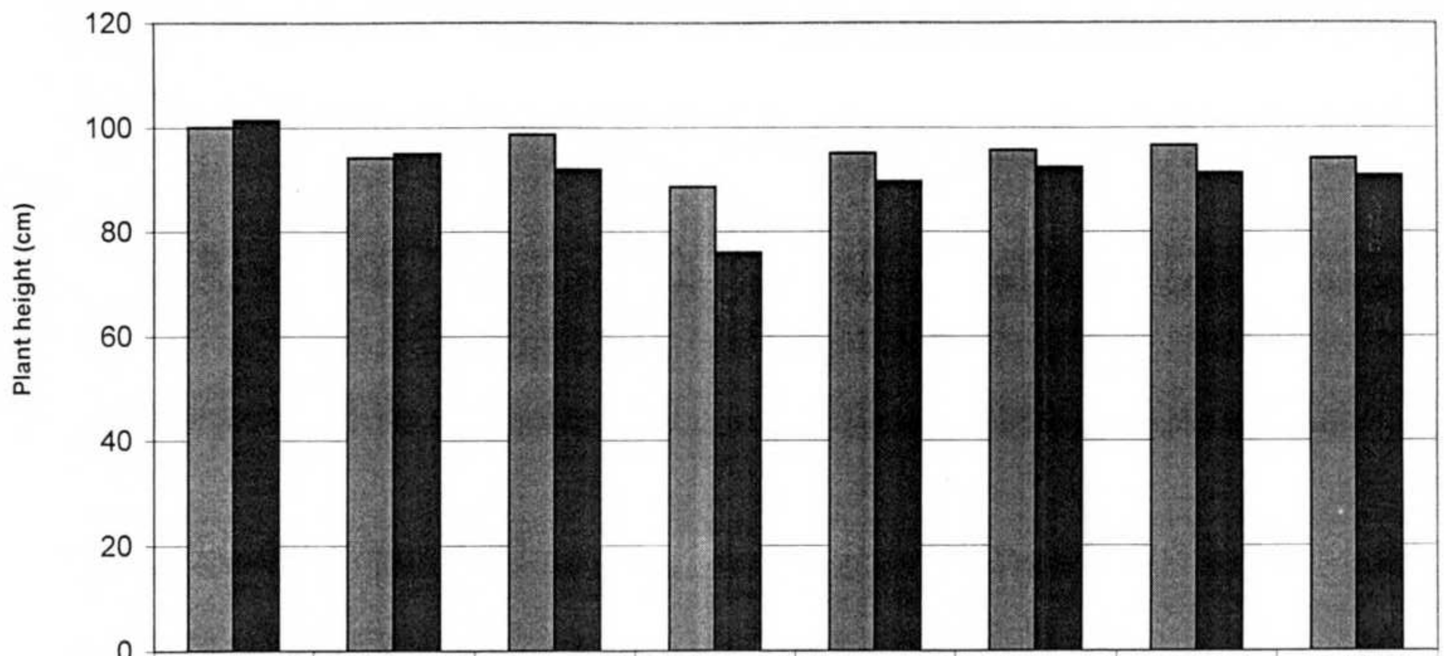
During late *Samba* season, the plant height at maximum tillering, panicle initiation and harvest stages as influenced by seedling age was observed to maintain the same trend i.e., planting of 25 days old seedlings registered the tallest plant height throughout the crop growth. However, it was on par with that of 32 days old seedlings at maximum tillering stage. At later stages upto harvest, the plant height due to 25 days old seedlings was on par with that of 39 days old seedlings and this was followed by 32 days old seedlings. Throughout the crop period it was found that planting of 46 days old aged seedlings was found to be poor in growth with the lowest plant height. Almost similar trend was observed in late *Thaladi* season at maximum tillering and panicle initiation stages, wherein 25 days old seedlings were found to produce significantly taller plants and 46 days old seedlings were found to result in significantly shorter plants. Similar results were observed by Koshta *et al.* (1987) and Singh *et al.* (1999) who reported that aged seedlings produced shorter plants. The reason was that the older seedlings remained in the nursery for longer periods in which it had attained tillering stage and when transplanted at older stage in the main field, it did not provide sufficient nutrients to vegetative growth, which led to reduction in plant height. However, the significance in plant height due to planting of seedlings of different ages was not observed at harvest stage in late *Thaladi* season. This may be attributed to weather elements during late *Thaladi* season. After planting, the crops developed from 25, 32 and 39



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ late Samba	74.24	72.53	70.84	62.42	70.93	69.09	71.24	68.78
■ late Thaladi	86.5	81.73	77.98	70.65	78.7	79.73	79.48	78.96

Treatments

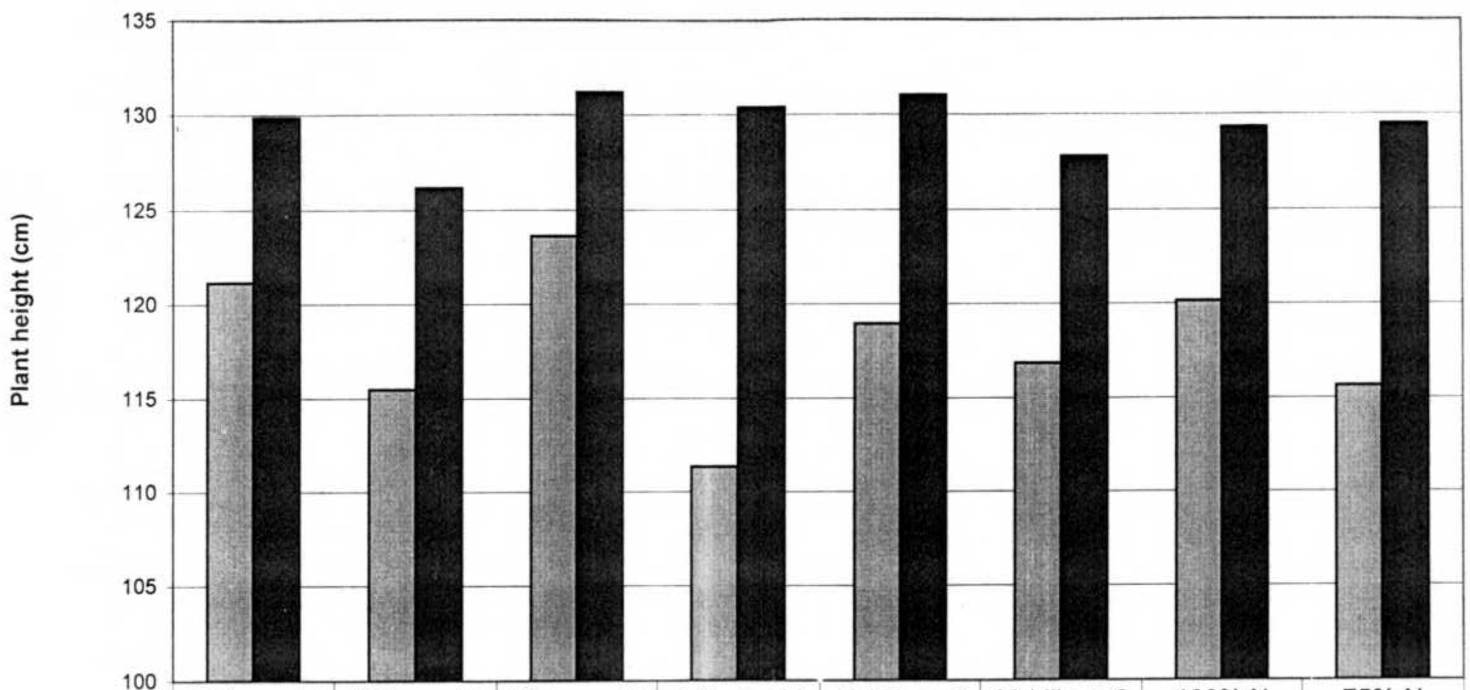
Fig.3 Effect of age of seedlings, plant population and nitrogen levels on plant height (cm) at maximum tillering stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	100.05	94.22	98.65	88.63	95.11	95.67	96.62	94.12
LATE THALADI	101.42	95.05	92	75.88	89.71	92.43	91.34	90.83

Treatments

Fig.4 Effect of age of seedlings, plant population and nitrogen levels on plant height at panicle initiation stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ LATE SAMBA	121.15	115.48	123.62	111.32	118.94	116.84	120.14	115.64
■ LATE THALADI	129.83	126.17	131.18	130.37	130.99	127.78	129.31	129.47

Treatments

Fig.5 Effect of age of seedling, plant population and nitrogen levels on plant height at harvest stage

days old seedlings experienced unfavorable rains after the panicle initiation stage, which led to stagnation of water and thereby affected the plant growth and ultimately the plant height. Whereas, after panicle initiation stage the crop produced from 46 days old seedlings had experienced very less rain. Hence its plant height did not get affected, therefore resulted in the comparable height at harvest. Besides this, the root growth (total root length) and root volume of crops derived from 25 to 39 days old were also affected as observed during maximum tillering stage (Table 15 and 16).

The overall reduction in root volume and root length in late *Thaladi* season as compared to late *Samba* season at maximum tillering stage is attributed to the lower maximum and minimum temperature, reduced sunshine hours and cool environment at that stage (Fig. 21 and 24). The increased plant height due to planting of 25 days old young seedlings could be ascribed to more seedling vigour and increased total root length hill^{-1} (9656 cm) as observed at maximum tillering stage (Table15). With the advancement of the age of the seedlings, the seedling vigour might have been reduced coupled with lesser root activity. The root length as observed at maximum tillering stage in rice plants derived from 46 days old seedlings was 7339 cm as compared to seedlings of other ages (9656, 9196 and 9617cm respectively for 25, 32 and 39 days old seedlings).

Application of 100 per cent nitrogen dose (150 kg ha^{-1}) was found to influence the plant height throughout the crop period than application of 75 per cent nitrogen (112.5 kg ha^{-1}) during late *Samba* season. This indicated that nitrogen was found to have positive effect on plant height. Similar results were also observed by Siddiqui *et al.* (1999), Rammohan *et al.* (2000), Chopra and Chopra (2000) and Lawal and Lawal (2002).

On the contrary, during late *Thaladi* season the impact of nitrogen levels was not significant on plant height. This might also be due to climatic factor. The initial top dressing coincided with rainfall and thereby there was excess stagnation of water in the field. The nitrogen applied during that time might have been quickly drained off due to flow of excess water; thereby there was no significant difference between two levels. The other reason would have been lesser absorption of nutrients including nitrogen due to lesser root growth and low minimum and maximum temperature that prevailed during early part of the crop growth during late *Thaladi* season. Similar reports were made by Janaki and Thiyagarajan (2002) who reported that low temperature during growth period lead to low uptake of nitrogen. During both seasons, the plant population did not affect the plant height.

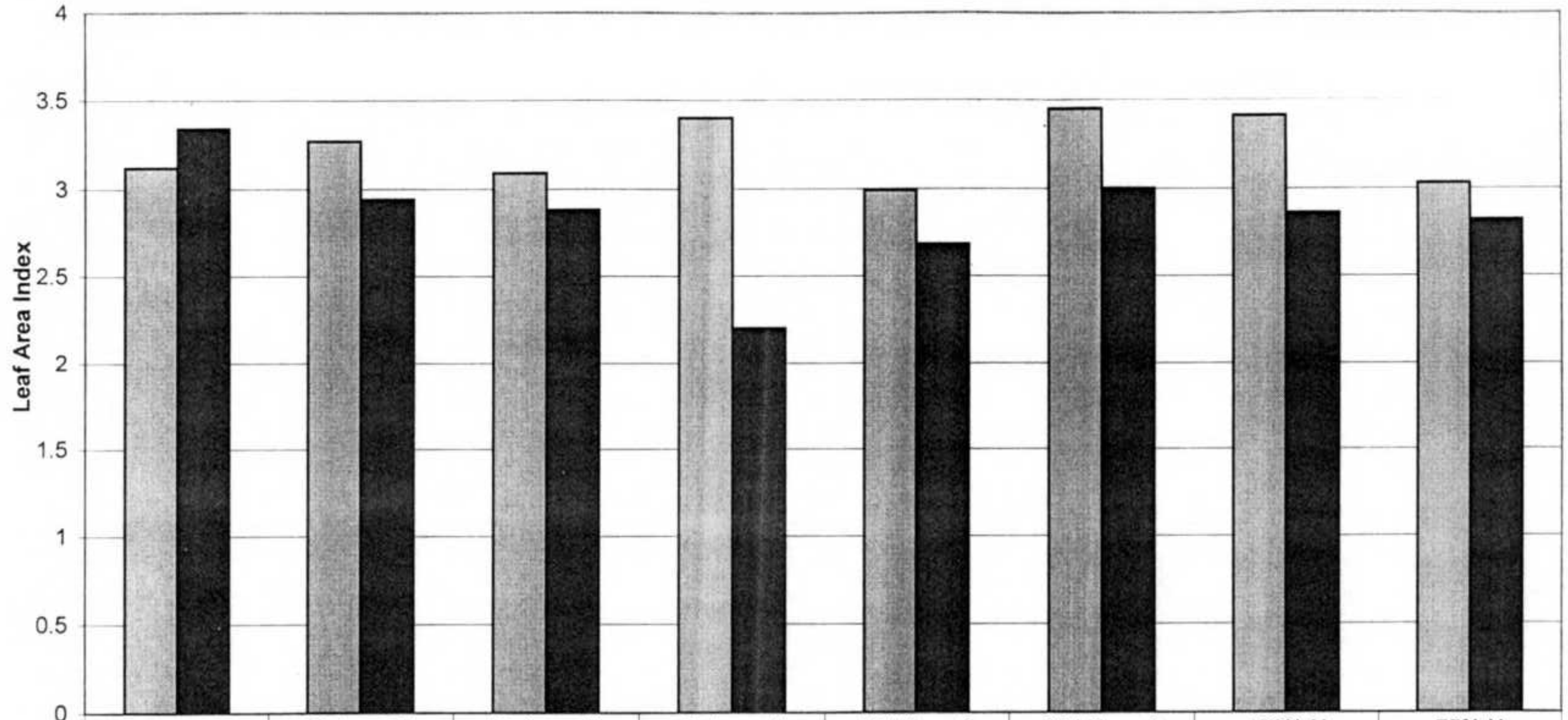
5.2. Number of leaves tiller^{-1}

Age of seedlings was found to influence the number of leaves tiller^{-1} only during maximum tillering stage in late *Samba* season. The number of leaves tiller^{-1} was significantly more due to planting of 46 days old seedlings (4.67) than seedlings of other ages, which were on par (3.63,3.87 and 3.63 leaves in 25, 32 and 39 days old seedlings, respectively). The more number of leaves tiller^{-1} due to planting of aged seedlings could be attributed to emergence of more young new leaves but small in size after the death of main shoots as new shoots takes rejuvenation from the new buds of old seedlings. However, with the advancement of age there was no significant difference in number of leaves tiller^{-1} among the different ages of seedlings.

The plant population, nitrogen levels and their interaction effects did not affect the number of leaves tiller^{-1} significantly during late *Samba* season (Table 17 and 18). Similarly none of the treatments have influenced the number of leaves tiller^{-1} significantly during late *Thaladi* season.

5.3. Leaf area index (Fig.6 and 7)

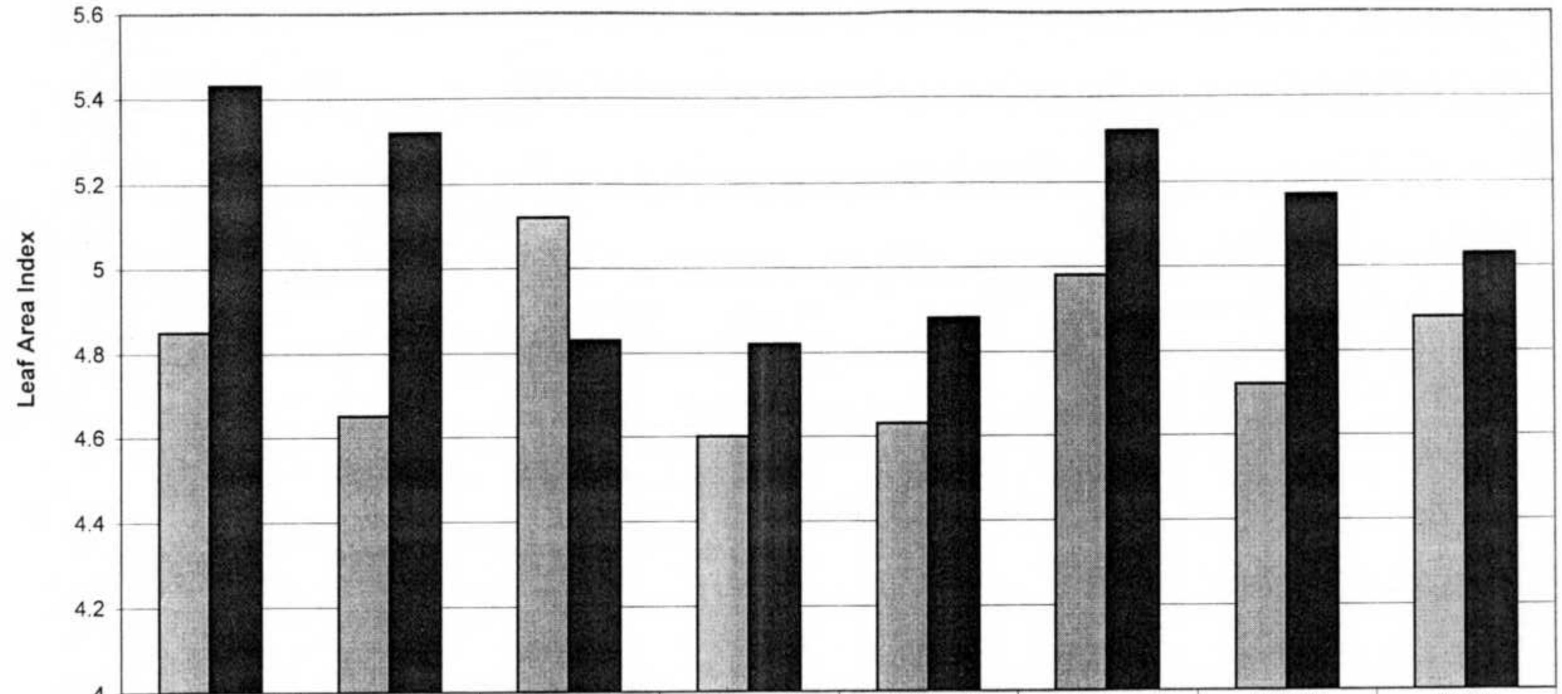
During late *Samba* season, the leaf area index was not influenced significantly due to age of seedlings, plant population and nitrogen levels and their interaction effects at maximum tillering and panicle initiation stages. However, the leaf area index was significantly affected by age of seedlings and plant population during late *Thaladi* season. Planting of 25 and 32 days old young seedlings were found to give high leaf area index at higher plant population of 66 hills m^{-2} as compared to 50 hills m^{-2} during both stages, maximum tillering and panicle initiation. However, planting of aged seedlings (39 and 46 days old) was found to give lesser leaf area index upto panicle initiation stage. The higher leaf area index due to planting of 25 and 32 days old young seedlings at higher plant population could be



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	3.12	3.27	3.09	3.4	2.99	3.45	3.41	3.03
LATE THALAI	3.34	2.94	2.88	2.2	2.68	3	2.86	2.82

Treatments

Fig.6 Effect of age of seedling, plant population and nitrogen levels on leaf area index at maximum tillering stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	4.85	4.65	5.12	4.6	4.63	4.98	4.72	4.88
LATE THALADI	5.43	5.32	4.83	4.82	4.88	5.32	5.17	5.03

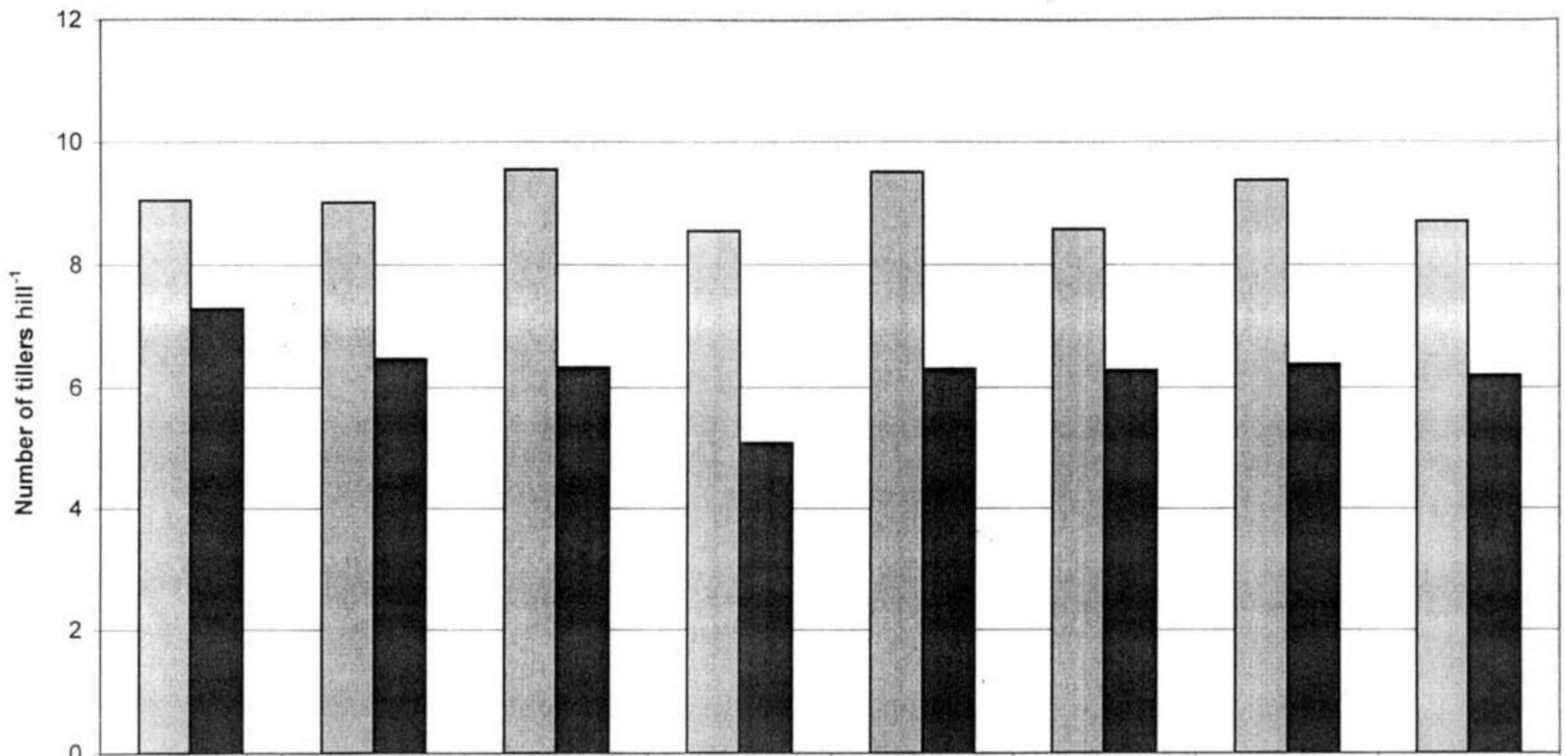
Fig.7 Effect of age of seedlings, plant population and nitrogen levels on leaf area index at panicle initiation stage

due to vigorous growth of young seedlings with fairly more number of leaves per tiller (Table 19 and 21). In general the leaf area index of *I.W.Ponni* rice variety was found to vary greatly due to different age of seedlings, plant population and nitrogen levels. Improper combination of either of these three leads to lesser leaf area index. But judicious combination of the above three factors were found to enhance the leaf area index considerably. Kandasamy and Ramasamy (1998) and Ray *et al.* (2001) also observed higher leaf area index at closer plant spacing due to longer leaves and more number of plants per unit area at Madurai.

5.4. Number of tillers hill^{-1} (Fig.8, 9 and 10)

The number of tillers hill^{-1} was not affected significantly due to age of seedlings during late *Samba* season. Whereas, during late *Thaladi* season planting of young seedlings of 25 and 32 days old produced more number of tillers hill^{-1}. This was mainly due to vigour of young seedlings. Planting of 39 and 46 days old seedlings produced lesser number of tillers hill^{-1} than young aged seedlings throughout the crop period as observed at maximum tillering, panicle initiation and harvest stages. Similar observations were made by Patel (1999) and Devi and Singh (2000) who reported that the concomitant effect of establishment of crop, less tillering period and less crop duration in the main field planted with aged seedlings resulted in lower number of tillers hill^{-1}.

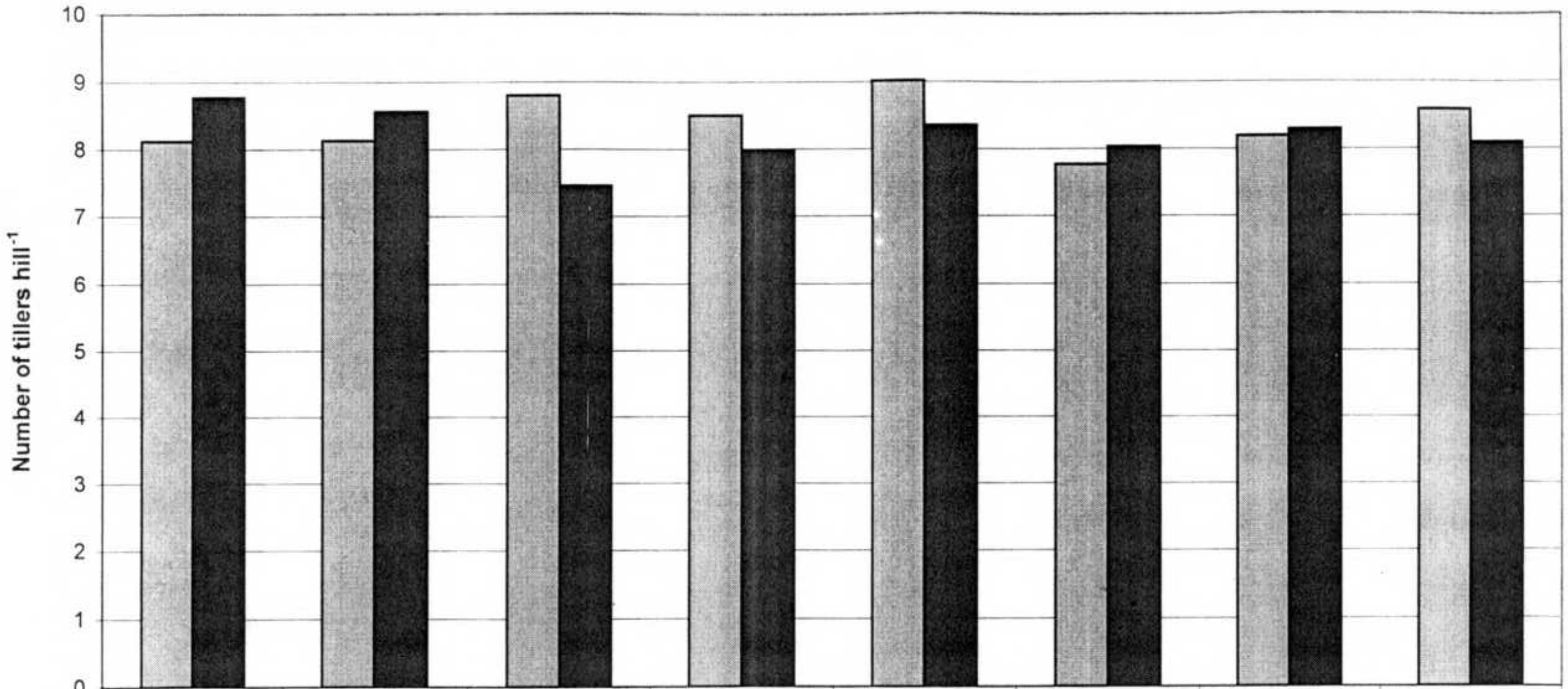
During late *Samba* season, recommended plant population of 50 hills m^{-2} was found to produce more number of tillers hill^{-1} than that of increased plant population of 66 hills m^{-2} at maximum tillering, panicle initiation and harvest stages. This might be due to competition for nutrients among the plants when plant population per unit area was increased. Similar results were reported by Jagannath *et al.* (1998) who observed increased number of tillers hill^{-1} at wider spacing. However, in the present study, plant population did not affect the number of tillers hill^{-1} during late *Thaladi* season. Lourduraj and Rajagopal (1999) also found that plant population did not affect the number of tillers hill $^{-1}$ during *Rabi* season at Aliyar Nagar (Tamil Nadu).



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	9.05	9.02	9.55	8.55	9.51	8.58	9.38	8.71
LATE THALADI	7.28	6.47	6.33	5.08	6.3	6.28	6.38	6.2

Treatments

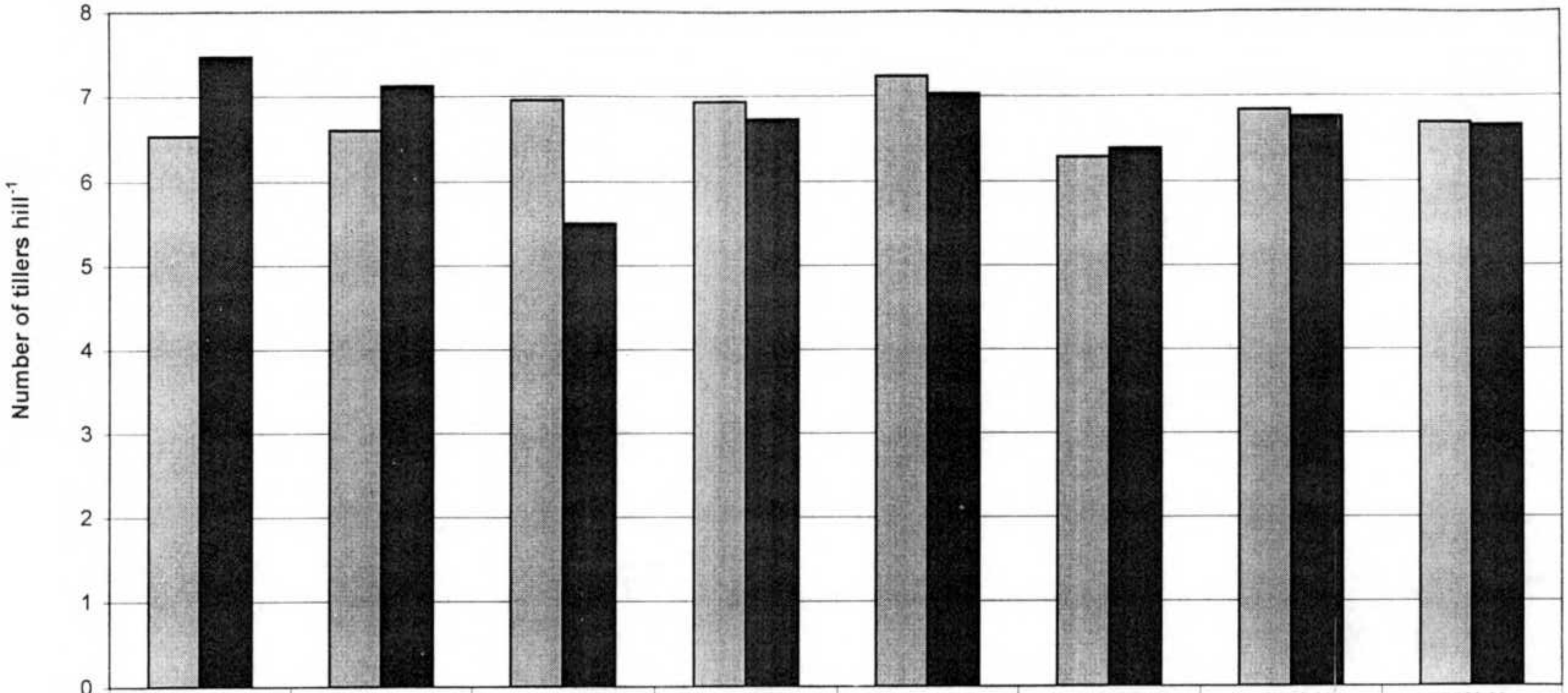
Fig.8 Effect of age of seedling, plant population and nitrogen levels on the number of tillers hill^{-1} at maximum tillering stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	8.12	8.13	8.8	8.5	9.01	7.77	8.19	8.58
LATE THALADI	8.77	8.56	7.45	7.98	8.35	8.03	8.29	8.09

Treatments

Fig.9 Effect of age of seedlings, plant population and nitrogen levels on the number of tillers hill^{-1} at panicle initiation stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ LATE SAMBA	6.53	6.6	6.95	6.93	7.23	6.28	6.83	6.68
■ LATE THALADI	7.47	7.12	5.5	6.72	7.02	6.38	6.75	6.65

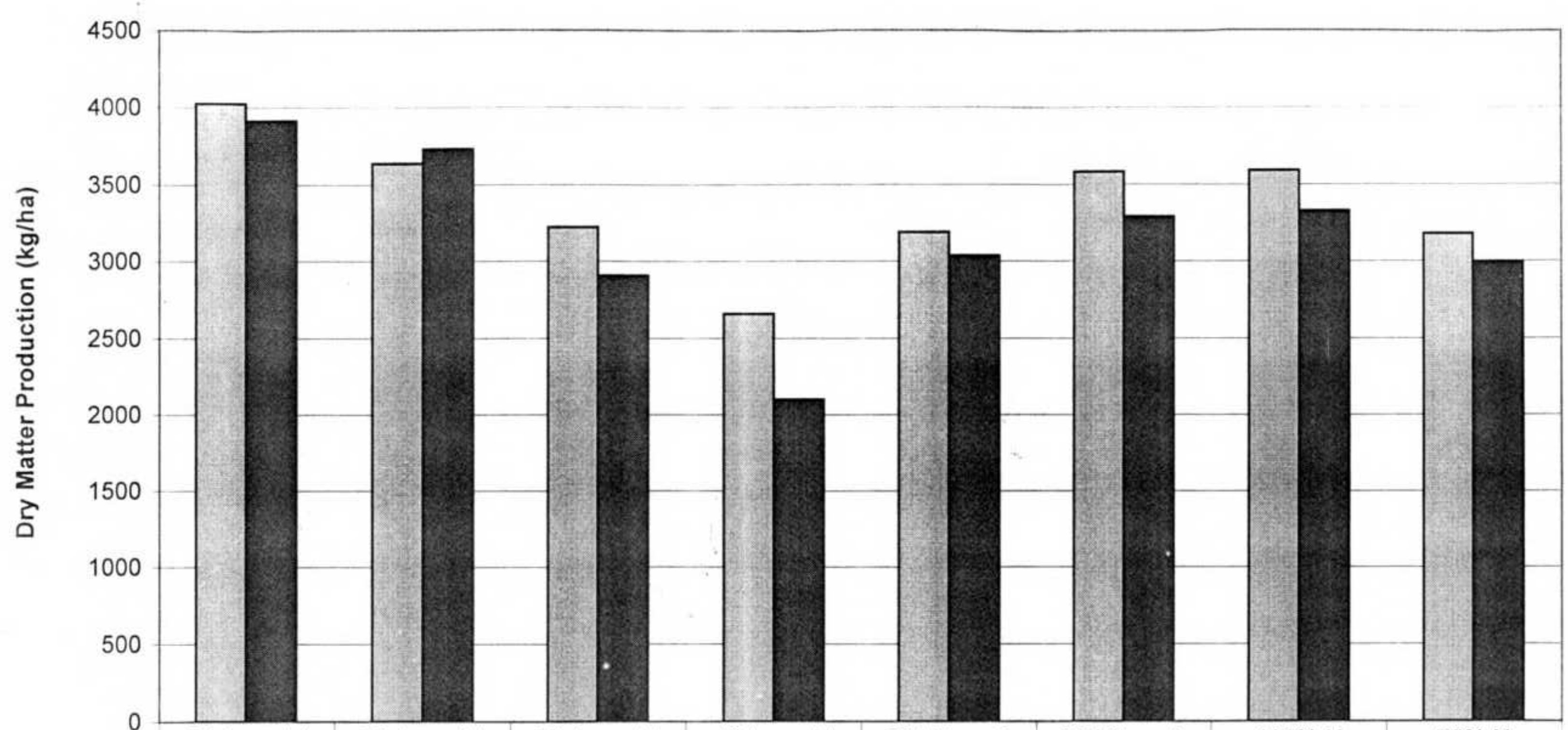
Treatments

Fig.10 Effect of age of seedlings, plant population and nitrogen levels on the number of tillers hill^{-1} at harvest stage

The number of tillers hill^{-1} was not influenced significantly by nitrogen levels and other interaction effects during both the seasons as observed at panicle initiation and harvest stages.

5.5. Dry matter production (Fig.11, 12 and 13)

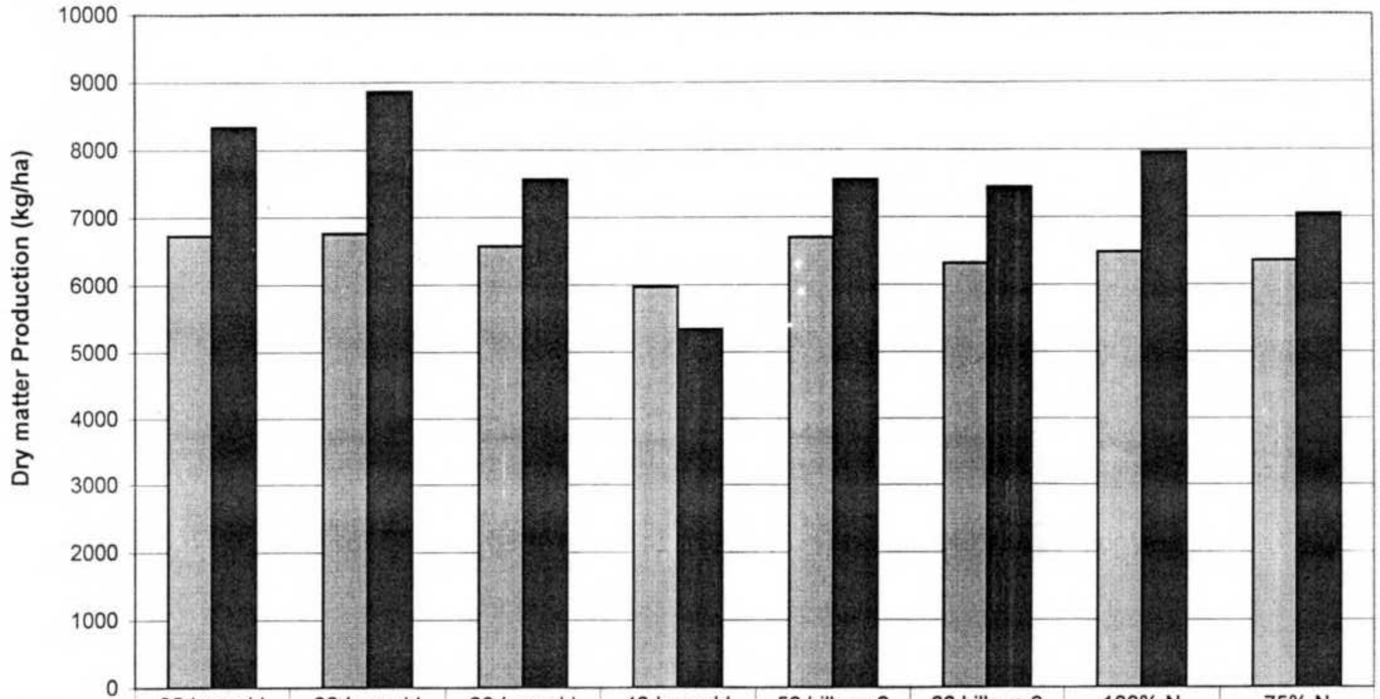
The total dry matter production (DMP) was influenced by age of seedlings, plant population and nitrogen levels only during maximum tillering stage in late *Samba* season. However, with the advancement of age of plants, none of the factors were found to influence the dry matter production significantly as observed at panicle initiation stage during late *Samba* season. On the contrary, both the age of seedlings and nitrogen levels were found to influence the dry matter production at maximum tillering and panicle initiation stages during late *Thaladi* season. But with the advancement of the age of the crop, after panicle initiation the dry matter production did not vary significantly due to various treatments as observed in both the seasons at harvest stage. This has clearly shown that even with the increase in plant density, the aged seedlings (46 days) could not accumulate more DMP or reduce the same significantly as compared to that of 25 days old seedlings. Similarly, planting of 46 days old seedlings even with reduced nitrogen (75% N) did not reduce the DMP drastically in *I.W.Ponni*. This result further indicated that the *I.W. Ponni* rice variety seems to be very plastic in nature and it could accumulate sufficient dry matter even with aged seedlings, irrespective of plant density to produce reasonably good grain yield. In general the dry matter production was found to have positive and significant relationship with grain yield (Table 62). The pooled analysis revealed seasonal variation in dry matter production, with more dry matter production during late *Thaladi* season than in late *Samba* season. This could be attributed to favourable weather parameters prevailed during crop growth in late *Thaladi* season as compared to late *Samba* season (Fig.19, 20 and 21). The late *Samba* crop suffered due to continuous rains with low day temperature coupled with less sunshine hours during maximum tillering to panicle initiation stage as well as at the fag end of its maturity. Venkateswaralu *et al.*(1977) and Krishna Kumar and Subramanian (1991) observed that the low temperature and insufficient light were



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ LATE SAMBA	4023	3637	3221	2657	3188	3581	3592	3177
■ LATE THALADI	3912	3730	2907	2098	3034	3289	3328	2995

Treatments

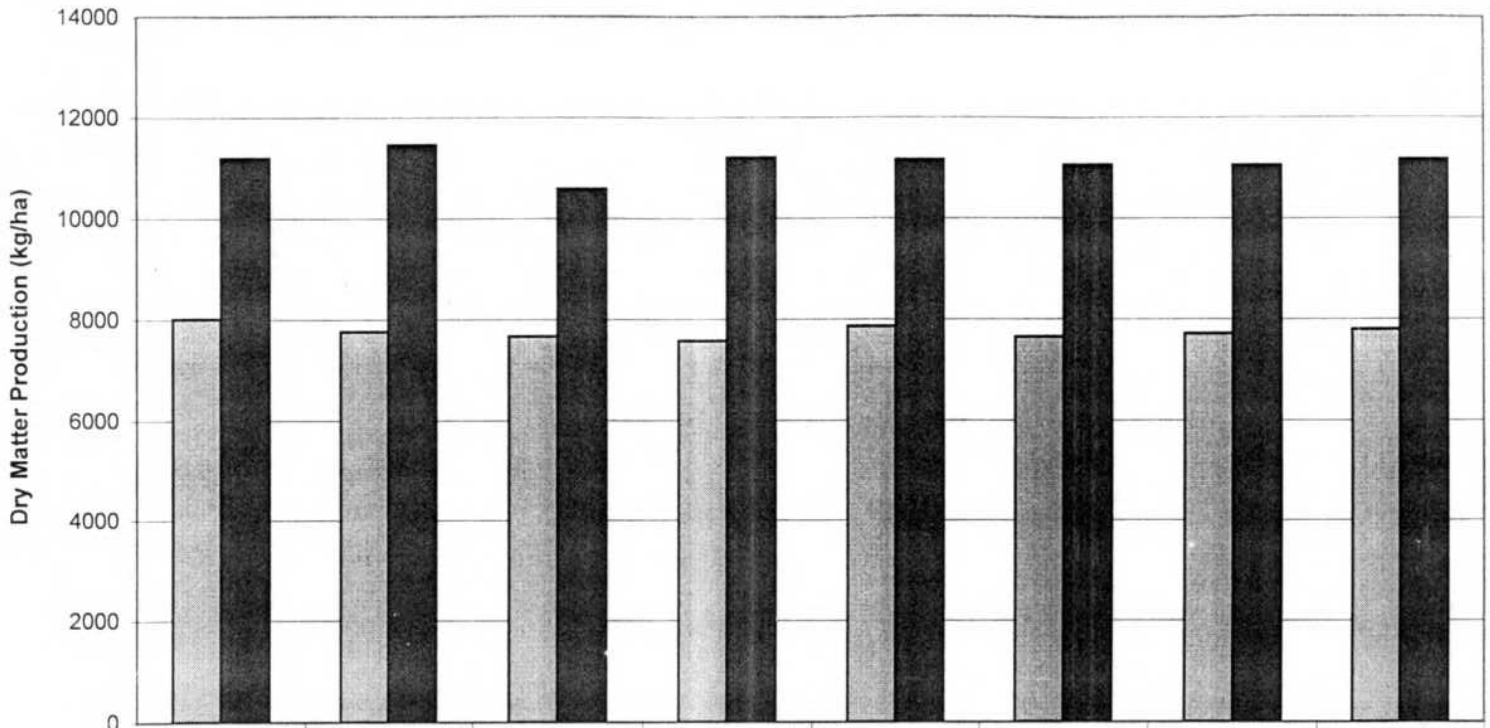
Fig.11 Effect of age of seedlings, plant population and nitrogen levels on dry matter production at maximum tillering stage



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ LATE SAMBA	6725	6758	6565	5965	6696	6310	6476	6351
■ LATE THALADI	8332	8856	7556	5335	7549	7440	7950	7039

Treatments

Fig.12 Effect of age of seedlings, plant population and nitrogen levels on dry matter production at panicle initiation stage



	1	2	3	4	5	6	7	8
□ Late Samba	8015	7769	7674	7579	7864	7655	7718	7801
■ Late Thaladi	11195	11455	10582	11205	11158	11061	11053	11163

Treatments

Fig.13 Effect of age of seedlings, plant population and nitrogen levels on dry matter production at harvest stage

not very conducive for proper growth and development of rice and hence, leads to low dry matter production.

5.6. Number of productive tillers hill^{-1} (Fig.14)

The number of productive tillers hill^{-1} did not vary due to age of seedlings during late *Samba* season. However, during late *Thaladi* season planting of 25,32 and 46 days old seedlings gave comparably higher number of productive tillers hill^{-1} than planting of 39 days old seedlings that gave the lowest number of productive tillers hill^{-1}. This was due to unfavourable rain immediately after planting of 39 days old seedlings (on the same day of planting there was 30.50 mm rainfall) which created stagnation of water in the field and hence, seedling establishment was affected. Consequently, 39 days old seedlings had produced significantly lower dry matter production (10582 kg ha^{-1} at harvest stage) than 46 days old aged seedlings (11205 kg ha^{-1}), which was not affected by rain. This was again clearly indicated by correlation studies in which the number of productive tillers did not contribute for grain yield as the productive tillers did not vary significantly due to age of seedlings.

The plant population affected the number of productive tillers hill^{-1} only during late *Samba* season, with more number of productive tillers hill^{-1} at recommended plant population than at increased plant population of 66 hills m^{-2}. Reduced competition for nutrients and space might be the reasons for more number of productive tillers hill^{-1} at 50 hills m^{-2}. Patra and Nayak (2001) reported earlier that wider spacing was found to result in more number of productive tillers hill^{-1}.

Nitrogen levels as well as other interaction effects did not have significant effect on number of productive tillers hill^{-1}.

5.7. Number of panicles m^{-2} (Fig.15)

During late *Samba* season, the age of seedlings did not affect the number of panicles m^{-2}. Similar observations were made by Kurmi *et al.* (1993). However, during late *Thaladi* season planting of young seedlings (25 and 32 days old) were found to produce more number of panicles m^{-2} than planting aged seedlings of 39 and 46 days old. The higher number of panicles m^{-2} in young seedlings might be contributed by the vigour of young seedlings, which could have produced more

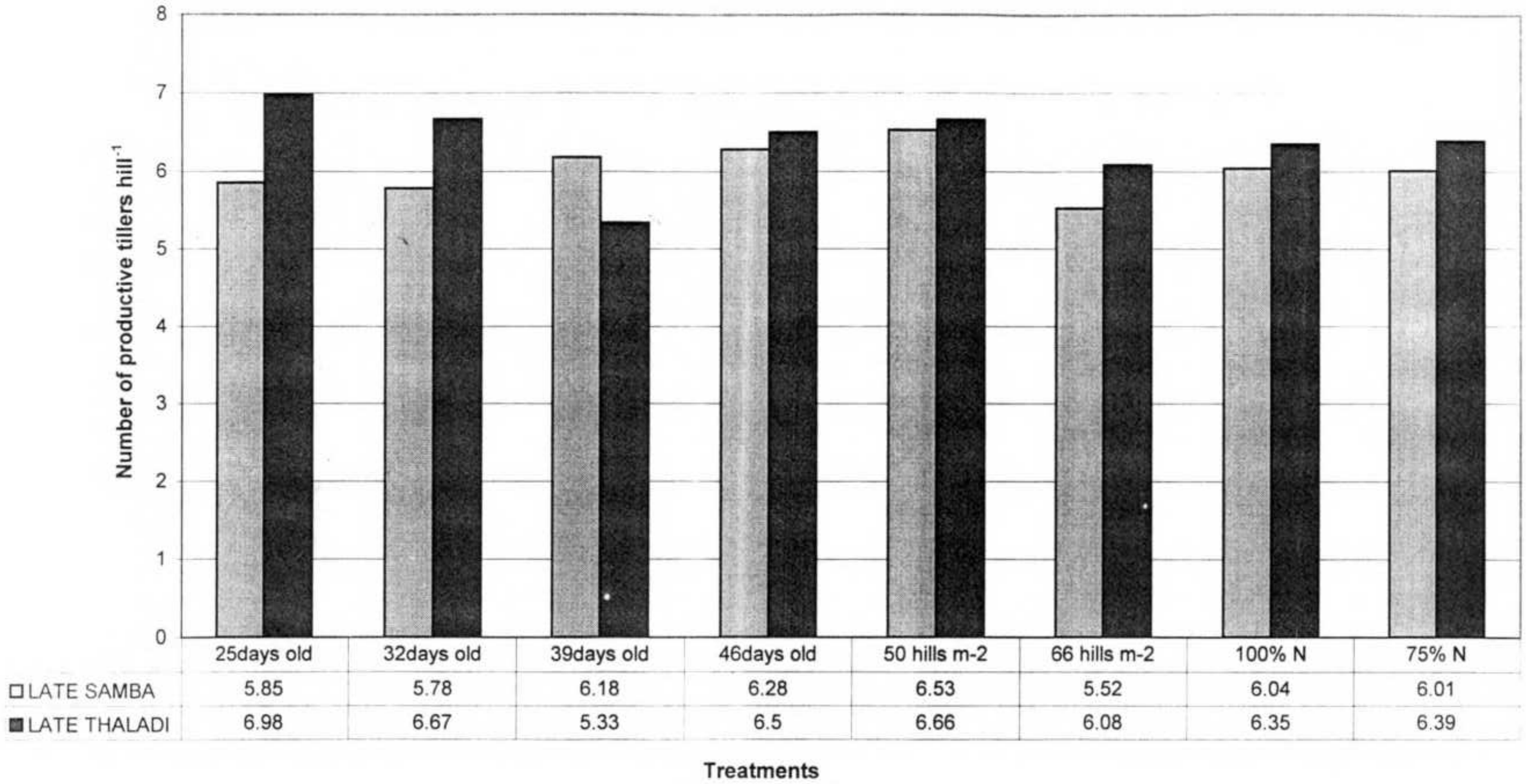


Fig.14 Effect of age of seedlings, plant population and nitrogen levels on the the number of productive tillers hill^{-1}

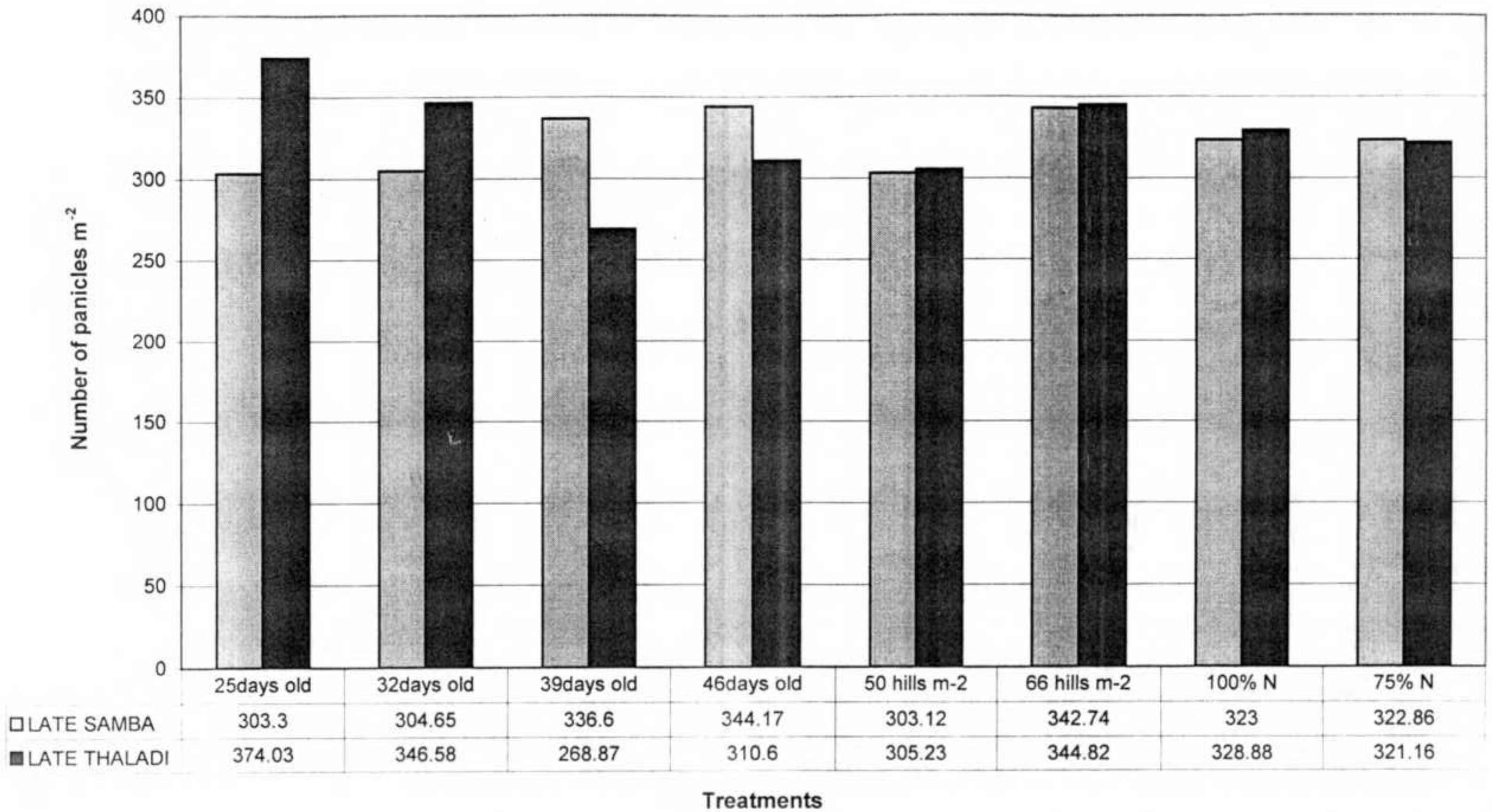


Fig.15 Effect of age of seedlings, plant population and nitrogen levels on the number of panicles m^{-2}

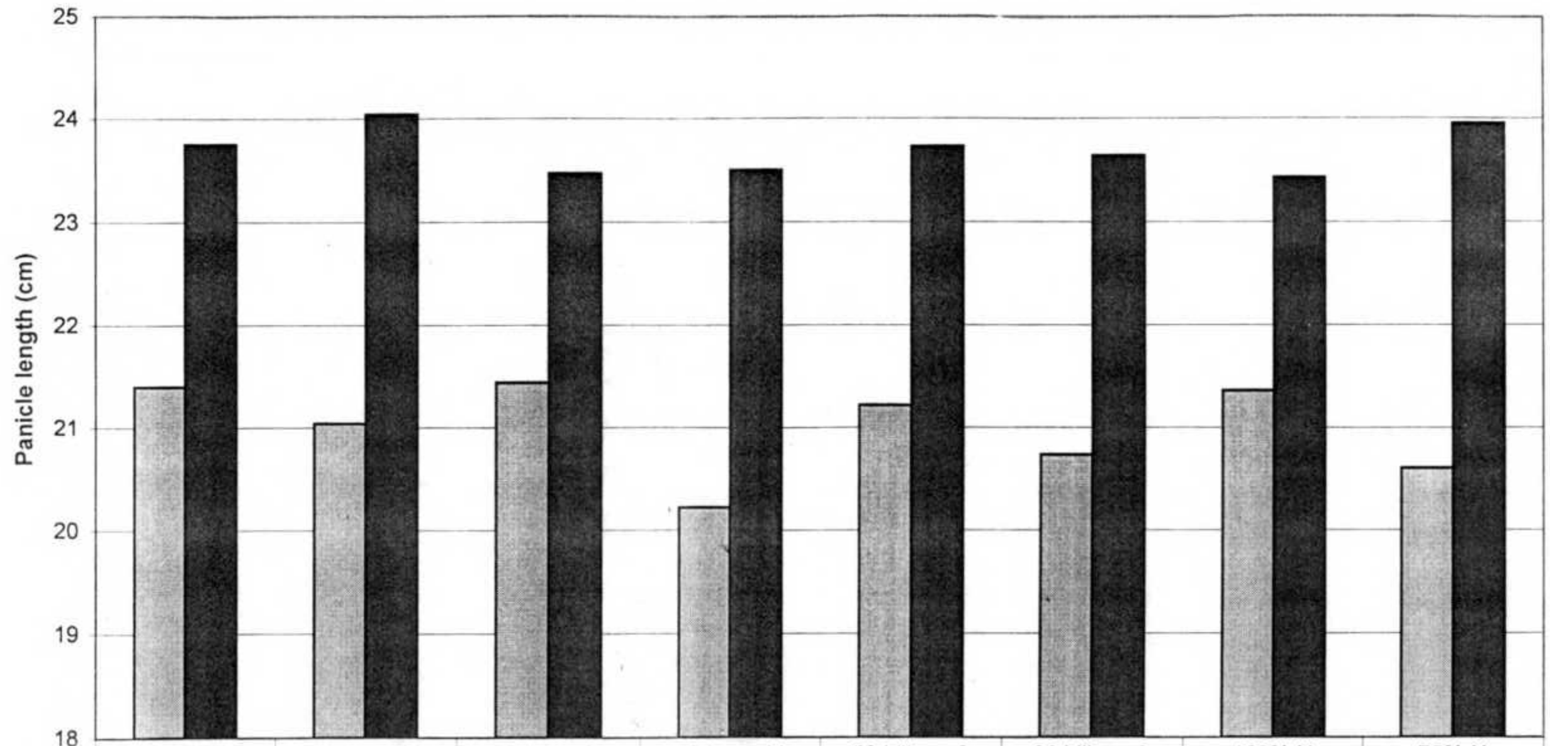
number of productive tiller m^{-2}. Similar results were observed by Singh and Singh (1998), Channabasappa *et al.* (1998) and Patel (1999) who reported that more tillering period, longer duration in mainfield and early establishment led to increased number of panicles m^{-2}, due to planting of young seedlings. However, pooled analysis in the present study ruled out the seasonal impact on the number of panicles m^{-2} (Table 37).

Plant population was found to influence the number of panicles m^{-2} during both seasons, with the highest number of panicles m^{-2} at an increased plant population of 66 hills m^{-2} than at recommended plant population of 50 hills m^{-2} (Table 36). This was mainly due to more number of hills per unit area at higher plant population. This is in corroboration with the findings of Ramasamy and Babu (1997), Shrivastava *et al.* (1999), Patel (1999), Chopra and Chopra (2000) and Kewu *et al.* (2001).

The nitrogen levels as well as other interaction effects did not have any significant impact on number of panicles m^{-2} during both seasons. This is in agreement with results obtained by Rajarathinam and Balasubramaniyan (1999). Pooled analysis has also confirmed that various treatments did not have significant impact on number of panicles m^{-2} (Table 37).

5.8. **Panicle length** (Fig.16)

The panicle length was affected by age of seedlings only during late *Samba* season. Planting of 25,32 and 39 days old seedlings produced comparably longer panicles than planting of 46 days old seedlings. This corroborates with the results of Singh and Singh (1998). However, the age of seedlings did not have much impact on panicle length during late *Thaladi* season. Similarly, plant population, nitrogen levels and other interaction effects did not have much impact on panicle length during both the seasons. But pooled analysis (Table 39) clearly indicated the effect of seasons on panicle length. The panicle length was longer during late *Thaladi* season (23.68 cm) than in late *Samba* season (20.98 cm). This might be due to the favourable climate from panicle initiation to harvest stage during late *Thaladi* season and unfavourable climatic conditions during late *Samba* season (Fig. 20, 21, 23 and 24). The correlation studies also revealed that panicle length contributed



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	21.4	21.04	21.44	20.22	21.22	20.73	21.36	20.6
LATE THALADI	23.75	24.04	23.47	23.5	23.73	23.64	23.43	23.95

Treatments

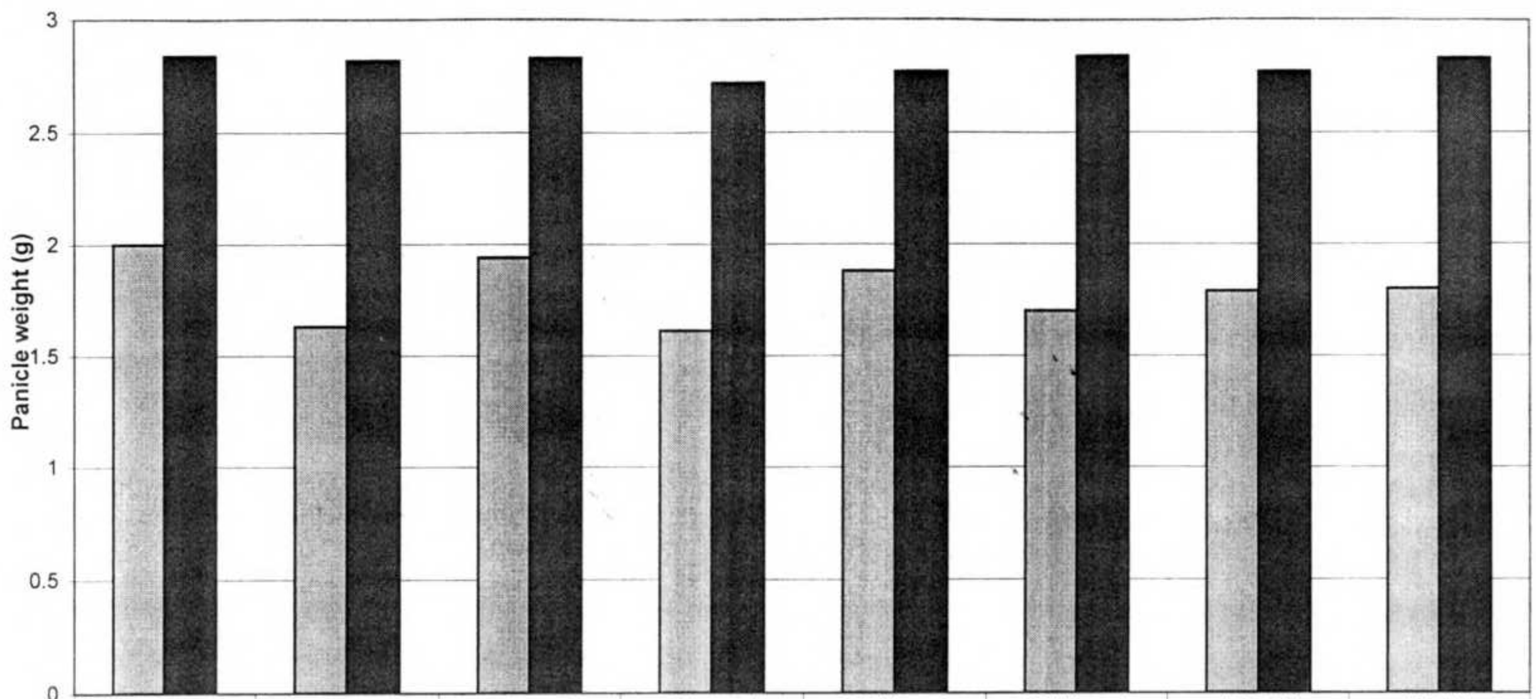
Fig.16 Effect of age of seedlings, plant population and nitrogen levels on panicle length (cm)

significantly to the grain yield during the late Thaladi season due to favourable climatic condition. Similar reports were made by Jayachandran et al. (2002) at Kerala, who opined that low light intensity during North-East monsoon season, particularly between panicle initiation and harvest stages was an important constraint for yield and yield components and the weather was found to affect the yield components rather than genetic potential of the crop.

5.9. Panicle weight (Fig.17)

As in the case of panicle length, the panicle weight was also high due to planting of 25 and 39 days old seedlings than 32 and 46 days old seedlings during late *Samba* season. However, the seedling age did not affect the panicle weight during late *Thaladi* season. Recommended plant population of 50 hills m^{-2} produced heavy panicles than that of increased plant population of 66 hills m^{-2}, which resulted in light panicles during late *Samba* season. But, plant population did not affect panicle weight during late *Thaladi* season. The increase in panicle weight due to planting of young seedlings might be attributed to early seedling vigour and better translocation of photosynthates for grain formation. The increase in panicle weight at recommended plant population might be due to lesser competition for nutrients among the tillers and better translocation and partitioning of photosynthates for grain development. Similar results were reported by Shrivastava *et al.* (1999) and Rajarathinam and Balasubramaniyan (1999).

The nitrogen levels and other interaction effects did not affect panicle weight during both seasons. The overall observation revealed that panicle weight was more during late *Thaladi* season than in late *Samba* season. Pooled analysis also confirmed this (Table 41). The average panicle weight was 2.80 g during late *Thaladi* season and 1.79 g in late *Samba* season. The production of heavier panicles during late *Thaladi* season was mainly due to favourable climatic condition that resulted in more number of filled grains $panicle^{-1}$ during late *Thaladi* season (161.36 to 170.67) than during late *Samba* season (77.60 to 94.88) (Table 42).



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
□ LATE SAMBA	2	1.63	1.94	1.61	1.88	1.7	1.79	1.8
■ LATE THALADI	2.84	2.82	2.83	2.72	2.77	2.84	2.77	2.83

Treatments

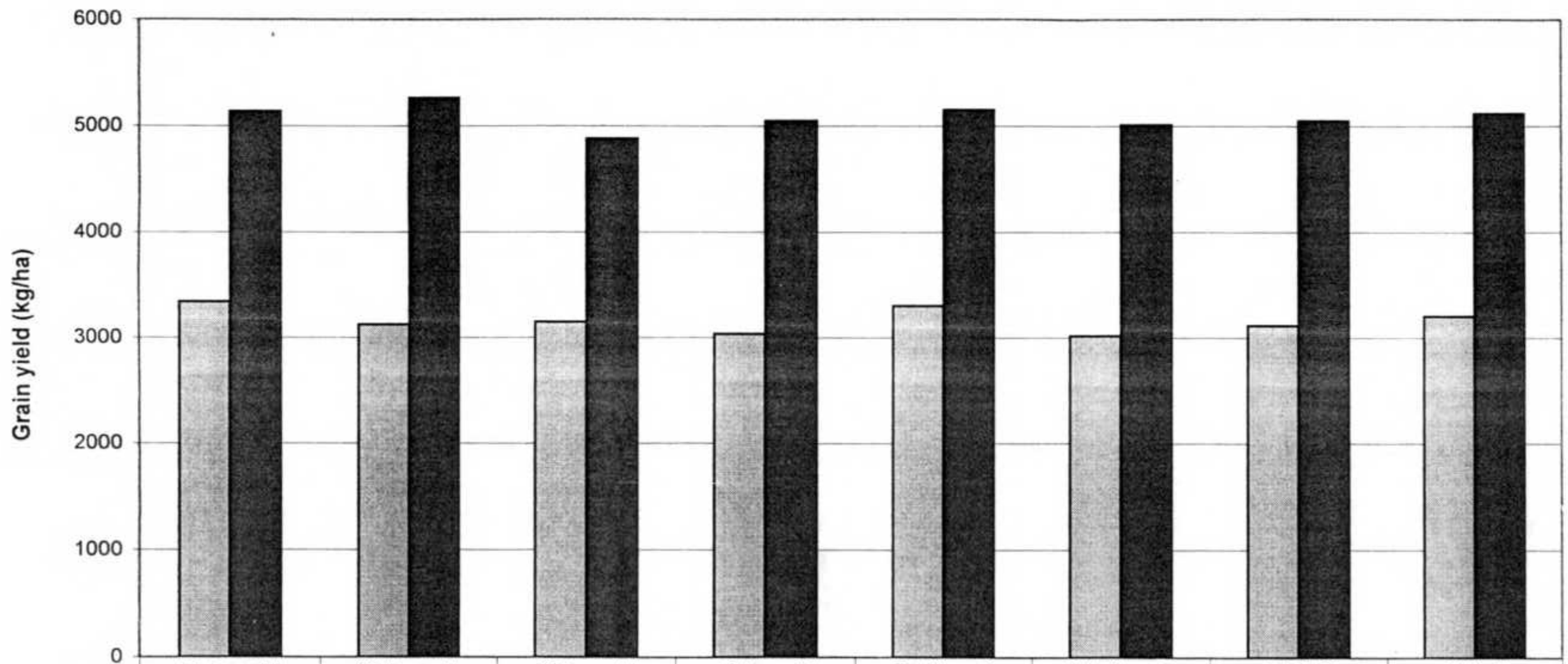
Fig.17 Effect of age of seedlings, plant population and nitrogen levels on panicle weight (g)

5.10. Grain yield (Fig.18)

The grain yield was not affected by age of seedlings during late *Samba* season. However, during late *Thaladi* season the age of seedlings influenced the grain yield. Planting of 32 and 25 days old seedlings gave significantly higher grain yield and were on par, followed by planting of 46 and 39 days old seedlings. This indicated that fairly younger seedlings could produce more grain yield than the older seedlings during late *Thaladi* season. Similar results were also observed by Reddy and Reddy (1991), Singh *et al.* (1996) and Devi and Singh (2000).

It was interesting to observe that the yield due to planting of 46 days old seedlings (5048 kg ha^{-1}) was also on par with that of 25 days old seedlings (5136 kg ha^{-1}) during late *Thaladi* season. The reduction in yield due to planting of 39 days old seedlings which recorded the lowest yield than that of 46 days old seedlings was due to high intensity rainfall. Since 8^{th} day of its planting (Date of planting: 30.11.2001), the crop planted with 39 days old seedlings which was in early to maximum tillering stage received almost continuous rains (coinciding with 51 and 52 standard week receiving 246.50 mm of rainfall in 6 rainy days)(Table 2, Appendix 6 and Fig.22). Further the same crop during its peak panicle initiation stage coincided with peak rainfall in December (539.50 mm). Hence, the tillering ability of 39 days old seedlings were affected in the early to maximum tillering stage and consequently the number of panicles m^{-2} were also affected at later stages (panicle initiation and harvest stage). Hence, the overall grain yield was lesser in crop planted with 39 days old seedlings planted crop than that of crops planted with other ages of seedlings.

Plant population as well as nitrogen levels and the various interaction effects did not affect the grain yield during both the seasons. From this result, it could be understood that increasing the plant population by 33 per cent (33% extra seedlings) either with young seedlings of 25 days old or with aged seedlings of 46 days old did not increase the final grain yield. Similarly reduction of nitrogen by 25 per cent (application of 75% of recommended N) did not reduce the grain yield significantly. This result revealed the fact that 25 per cent nitrogen (37.5 kg N ha^{-1}) could be saved from the existing dose of 150 kg ha^{-1} without loss of grain yield in *I.W. Ponni* rice variety. This had further indicated that *I.W.Ponni* seems to be a low



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	3341	3122	3148	3033	3304	3018	3114	3207
LATE THALADI	5136	5264	4880	5048	5152	5012	5048	5116

Treatments

Fig.18 Effect of age of seedlings, plant population and nitrogen levels on grain yield (kg/ha)

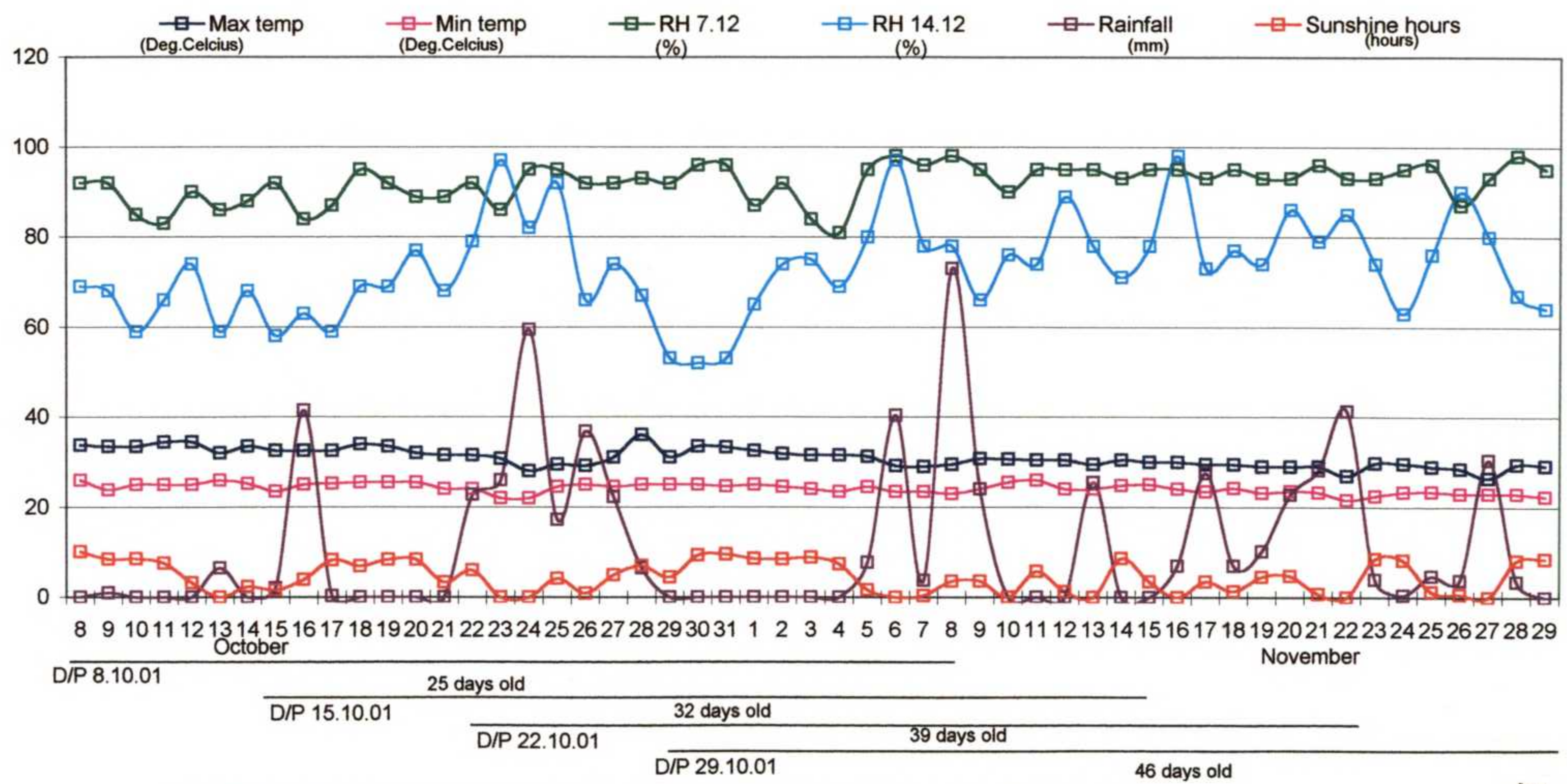


Fig.19 Weather parameters at maximum tillering stage during late *Samba* season

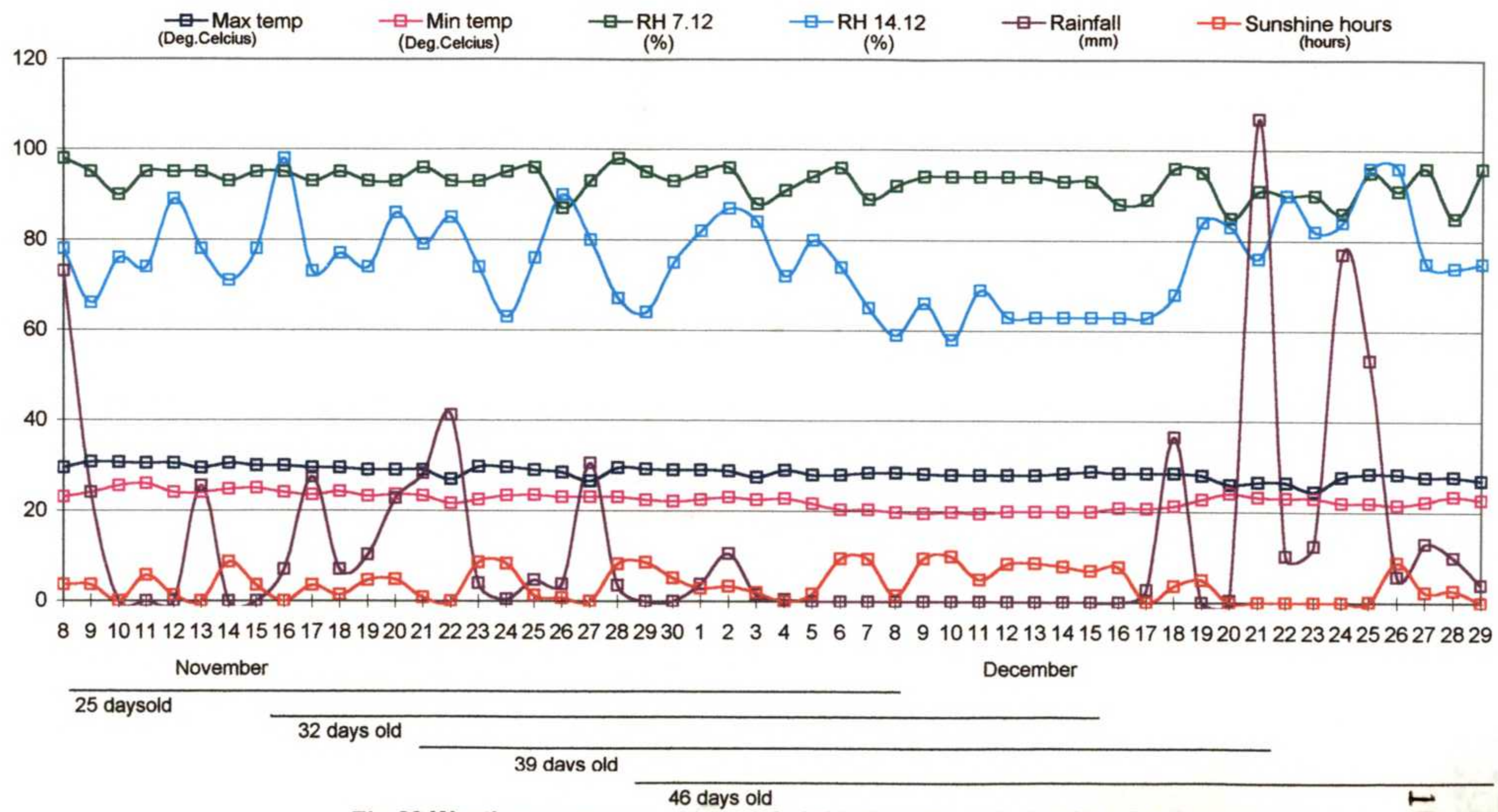


Fig.20 Weather parameters at panicle initiation stage during late *Samba* season

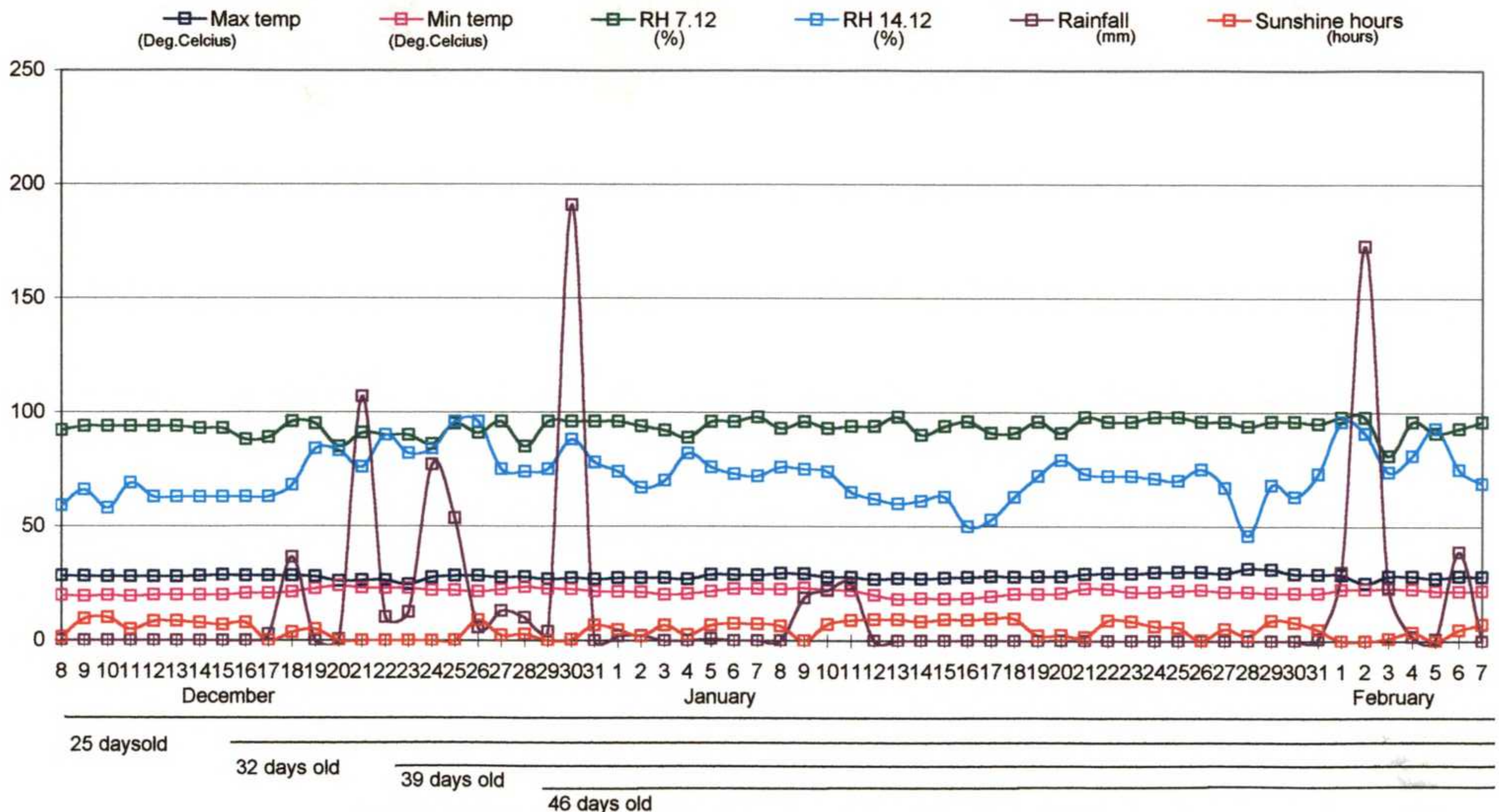


Fig 21. Weather parameters at harvest stage during late Samba season

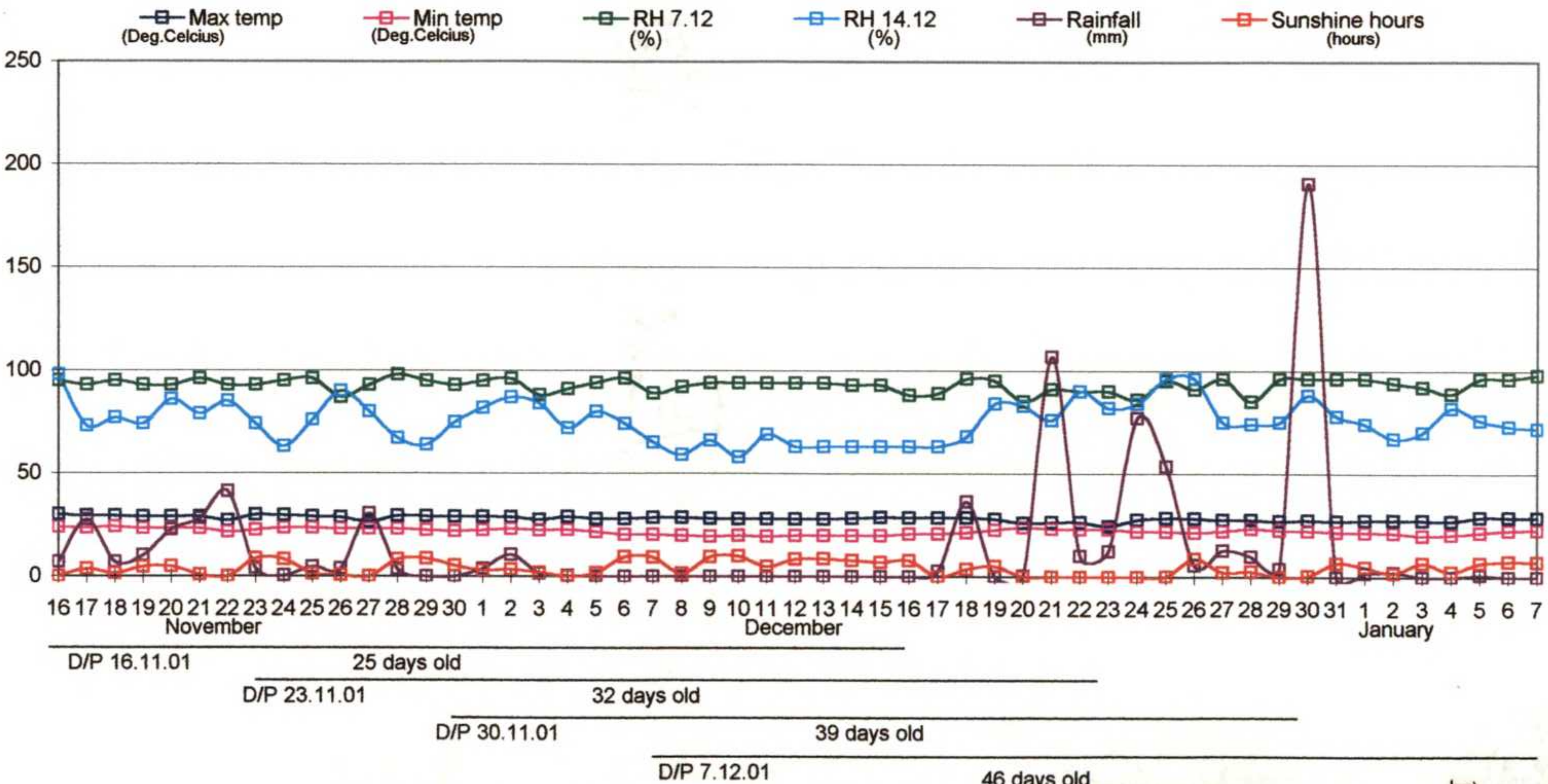


Fig 22. Weather parameters at maximum tillering stage during late Thaladi season

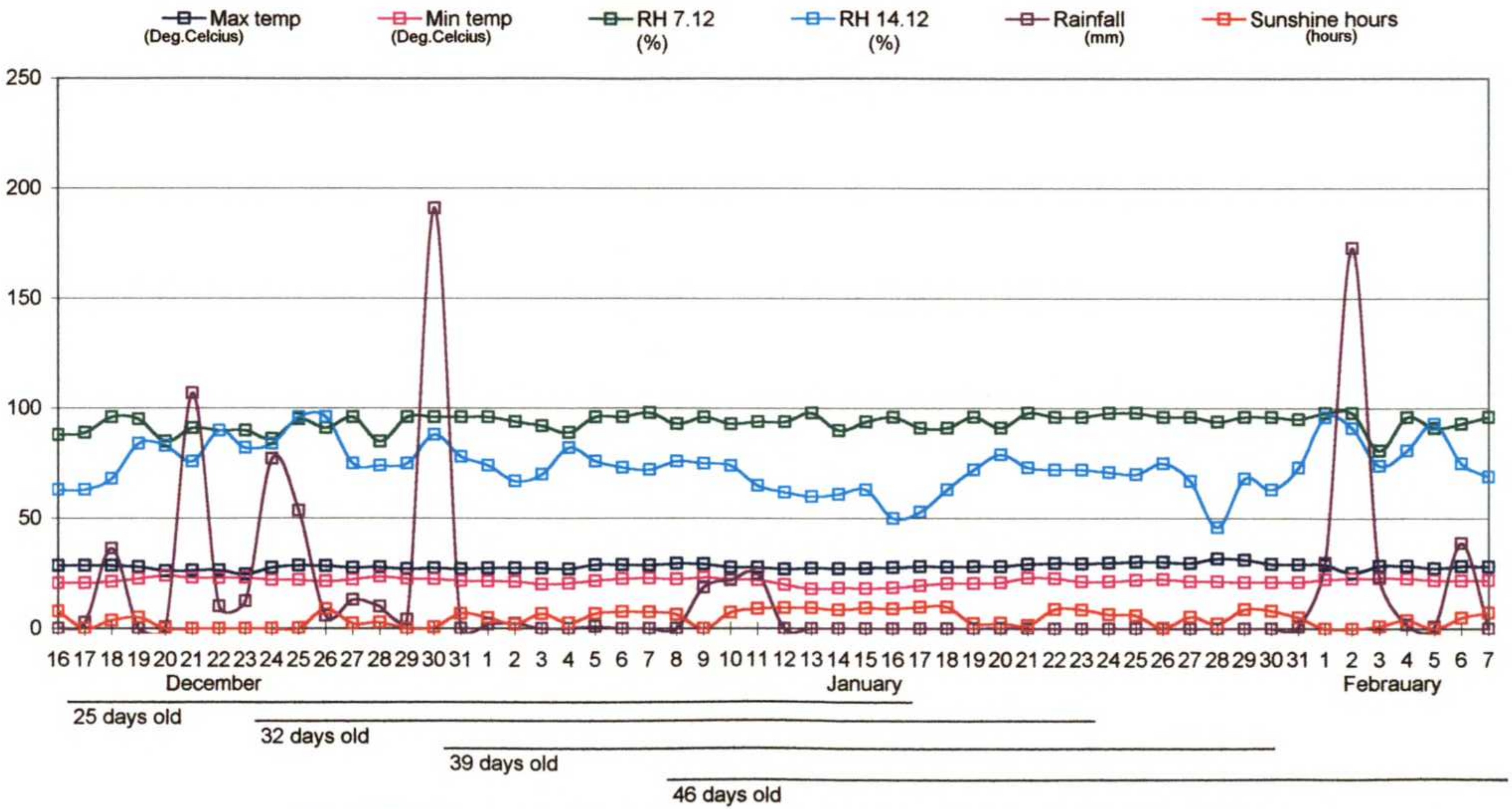
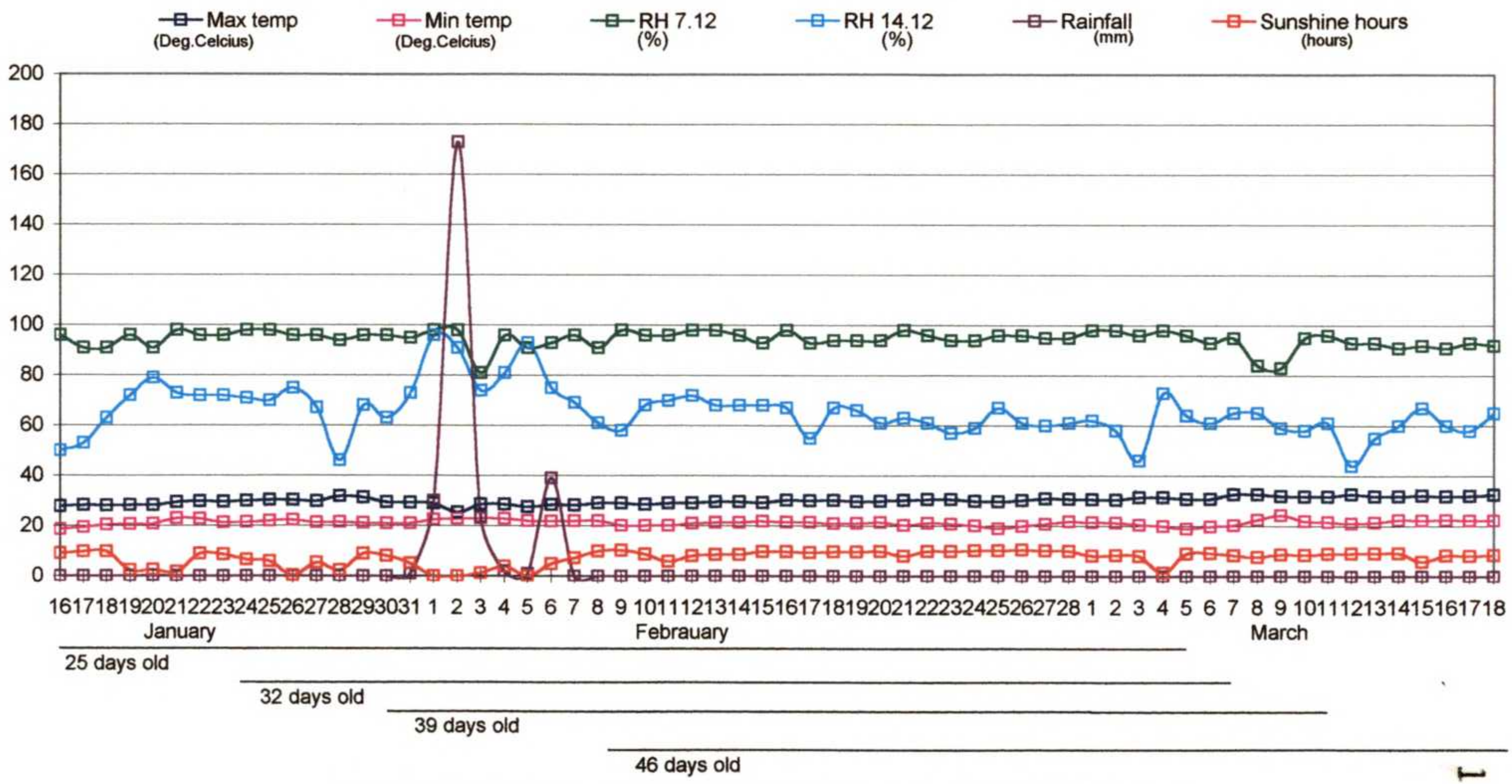


Fig 23. Weather parameters at panicle initiation stage during late *Thaladi* season



Firg 24. Weather parameters at harvest stage during late *Thaladi* season

fertilizer responsive rice variety but with high yielding capacity. Two decades back there was a very popular rice variety in Tamil Nadu which was also a low fertilizer responsive variety called "*Bhavani*" with high yielding capacity like that of *I.W.Ponni* even at low dose of 75 kg ha^{-1}. Low fertilizer responsiveness means high fertilizer use efficiency. Janaki and Thiyagarajan (2002) reported that the medium duration genotypes were found to acquire less nitrogen as compared to short duration rice genotypes and have high absorption efficiency. On the contrary, *I.W.Ponni* being a medium duration rice variety seems to have more absorption efficiency and hence it was able to produce more grain yield even at 75 per cent of recommended dose of N (112.5 kg ha^{-1} probably due to more root activity (root length and root volume). This is in turn might be due to the genetic potentiality of the variety to give higher yield with low N.

The overall yield level was high during late *Thaladi* season as compared to late *Samba* season at all the treatments. This was also confirmed by pooled analysis (Table 49) which revealed the seasonal effect on grain yield. The average yield level was 5082 kg ha^{-1} in late *Thaladi* season as against 3161 kg ha^{-1} in late *Samba* season. This accounts for about 61 per cent higher yield in late *Thaladi* than late *Samba* season. The increase in overall yield in all the treatments during late *Thaladi* season might be attributed to favourable climatic conditions throughout the cropping period (Fig.22, 23 and 24). The reason for overall increase in yield in late *Thaladi* season might be attributed to mainly the timely rainfall. In late *Samba* season, irrespective of the age of seedlings planted, the flowering stage of the crop coincided with rainfall (49^{th} to 52^{nd} standard week; 539.95 mm rainfall) (Fig.20 and Appendix 5). Hence, the spikelet sterility might have been affected. Similarly, during the fag end of the crop, irrespective of age of seedlings planted, there was an unusual rain in February 2002 (5^{th} standard week with 229.50 mm rainfall) (Table1, Fig.21 and Appendix 5) which lodged the standing crop which were in different stages (25 and 32 days old seedlings planted crop were in harvest stage, 39 and 46 days old seedlings planted crop were in grain filling stage). Because of lodging there was some grain loss in the crop which was in fact ready for harvest and the grain filling was affected in the late planted crops with 39 to 46 days old seedlings which might have resulted in more chaff and consequently led to reduced grain yield (Table 48) as compared to late *Thaladi* season. In addition to rain, the other weather parameters such as maximum and minimum temperature and sunshine hours were also not favourable from panicle initiation to harvest stage of the late *Samba* crop. Upto maximum tillering stage, the maximum and minimum temperatures were 31.8°C and 24.5°C, respectively (standard week 46 to 1; Appendix 5). Whereas, after maximum tillering stage from panicle initiation to harvest stage, the maximum and minimum temperatures were low (24-28°C and 21-22°C, respectively) and sunshine hours were also less (4-6 hours per day)(Appendix 5).

On the contrary, during late *Thaladi* season, irrespective of the age of seedlings planted, the crop did not suffer due to excess rains and in fact enjoyed more sunshine hours and higher maximum temperature from panicle initiation to maturity stage (5.6 to 7.8 hours and 28 to 31°C) (Fig.23 and 24 and Appendix 6). Because of this favourable climatic conditions, the late *Thaladi* crop, irrespective of age of seedlings (time of planting) had favourable growth in terms of the highest DMP (11110 kg ha^{-1}), longer panicles (23.68 cm), heavier panicles (2.80g), more number of filled grains $panicle^{-1}$ (166.51) and total grains $panicle^{-1}$ (203.06) as compared to the late *Samba* crop, which recorded low DMP (7759 kg ha^{-1})' lesser panicle length (20.98 cm), lesser panicle weight (1.79g), lesser number of filled grains $panicle^{-1}$(85.20) and lesser total number of grains $panicle^{-1}$(105.43). Moreover, because of favourable climatic conditions, the uptake of NPK as a function of higher DMP was recorded in late *Thaladi* crop than late *Samba* crop. The uptake of N, P and K were 129.04, 11.52 and164.97 kg ha^{-1}, respectively during late *Thaladi* season and 95.54, 9.78 and 108.32 kg ha^{-1}, respectively during late *Samba* season. Chowdhury and Gore (1991) reported that combination of maximum temperature of 30.5°C, 81 per cent relative humidity and rainfall of 1000 mm during physiological growth phases is ideally suited to give optimum rice yield. In the present study, during late *Thaladi* season there was more sunshine hours during later parts of plant growth when compared to late *Samba* season, which might have resulted in improved grain yield (Fig.21 and 24). Similar results were observed earlier by Janardhan *et al.* (1980) and Jayachandran *et al.* (2002) who reported that rice grain yield was associated with the solar radiation during later parts of the growth period and low light during primordial initiation to flowering or from flowering to harvest was more detrimental to yield. The late *Samba* crop encountered more rains during maturity stage (Fig.21) and this might have resulted in lowering of grain yield. Sreenivasan and Banerjee (1978) and Viswambaram *et al.* (1989) reported a negative correlation between rain and yield during maturity stage and additional rainfall above the normal was found to exert negative influence during sowing, tillering and flowering stages of the crop. In the present study, the late *Samba* crop received 840 mm rainfall in 19 rainy days. Hence, it might have resulted in lesser grain yield in late *Samba* than in late *Thaladi*.

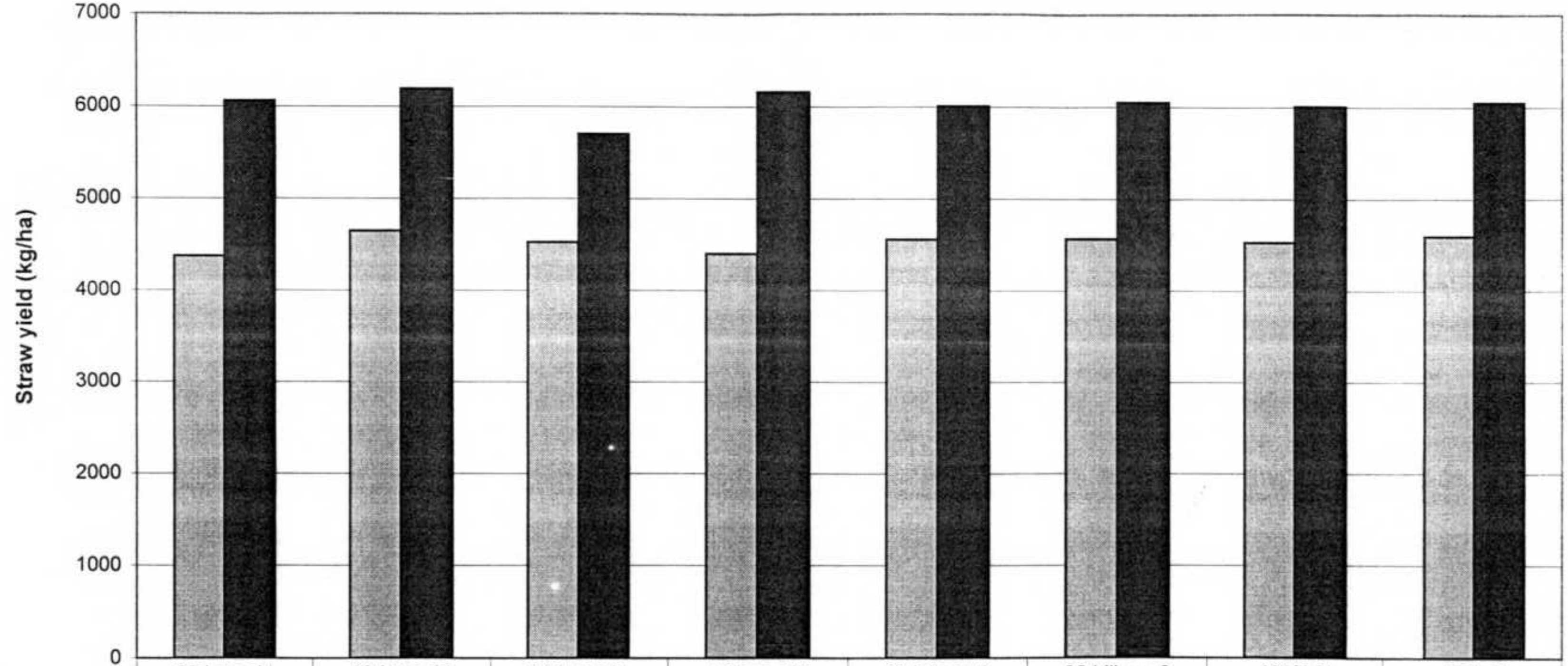
The Agronomic Nitrogen Use Efficiency (Appendix 1) was increased when 75 per cent of the recommended dose of nitrogen (112.5 kg ha^{-1}) was applied irrespective of age of seedlings and plant population during both seasons, besides saving 25 per cent nitrogen (37.5 kg ha^{-1}). The Agronomic Nitrogen Use Efficiency had increased with decrease in nitrogen level in all the treatments. The Agronomic Nitrogen Use Efficiency was higher when 25 days old seedlings with 66 hills m^{-2} at 75 per cent nitrogen (30.62), followed by 32 days old seedlings with 66 hills m^{-2} at 75 per cent nitrogen (29.96), 25 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen (29.93), 39 days old seedling at 50 hills m^{-2} with 75 per cent nitrogen (29.12) and 46 days old seedling at 50 hills m^{-2} with 75 per cent nitrogen (29.04) during late *Samba* season. During late *Thaladi* season, the Agronomic Nitrogen Use Efficiency was very high when 25 days old seedlings was planted at 50 hills m^{-2} with 75 per cent nitrogen (49.37), followed by 32 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen (47.31), 46 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen (46.85) and 32 days old seedlings at 66 hills m^{-2} with 75 per cent nitrogen (46.40). The overall Agronomic Nitrogen Use Efficiency was higher during late *Thaladi* season (39.68 kg grains/ kg N) than during late *Samba* season (24.64 kg grains/ kg N) (Appendix 1). The reason for this higher Agronomic Nitrogen Use Efficiency at 75 per cent nitrogen might be due to favourable weather conditions prevailed in late *Thaladi* season.

5.11. Straw yield (Fig.25)

The straw yield was also not influenced due to age of seedlings, plant population, nitrogen levels and their interaction effects during both seasons. This indicated that even with increased plant population, the straw yield did not proportionately increase. Similarly, even by reducing 25 per cent of nitrogen from the recommended level the straw yield was not affected significantly. Also the straw yield was not affected due to planting of 46 days old aged seedlings as compared to 25 days old seedlings. The pooled analysis (Table 51) also confirmed that there was no treatmental variation in respect of straw yield. The average straw yield in late *Thaladi* season was 6028 kg ha^{-1} as against 4562 kg ha^{-1} during late *Samba* season. This accounts for about 3.2 per cent increase in straw yield in late *Thaladi* season as compared to late *Samba* season. Correlation studies indicated that straw yield at harvest was found to influence the grain yield significantly during both the seasons (table 62).

5.12. Harvest index

Similar to straw and grain yield, the harvest index was also not influenced by the age of seedlings, plant population, nitrogen levels and the various interaction effects during both the seasons (Table 52). Since grain as well as straw yields were not significantly affected due to various treatments, the harvest index was also not influenced significantly due to various treatments, as harvest index is only a ratio between grain yield and total biomass. The overall harvest index was also fairly high as that of straw and grain yield during late *Thaladi* season as compared to late *Samba* season. Harvest index usually refers to the partitioning of dry matter into grain. In that analogy, it could be stated that better partitioning of dry matter into grain had occurred during late *Thaladi* season due to favourable climatic conditions. The unfavourable climatic conditions prevailed during flowering to harvest stage in late *Samba* crop may be the reason for reduced grain yield and harvest index. Murty and Sahu (1986) reported that low light at anthesis lead to low harvest index. In the present study, unfavorable weather parameters prevailed during the later parts of the late *Samba* crop (from panicle initiation to harvest stage) might have led to low harvest index.



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
LATE SAMBA	4374	4648	4526	4400	4560	4564	4530	4594
LATE THALADI	6060	6192	5702	6157	6007	6049	6005	6050

Treatments

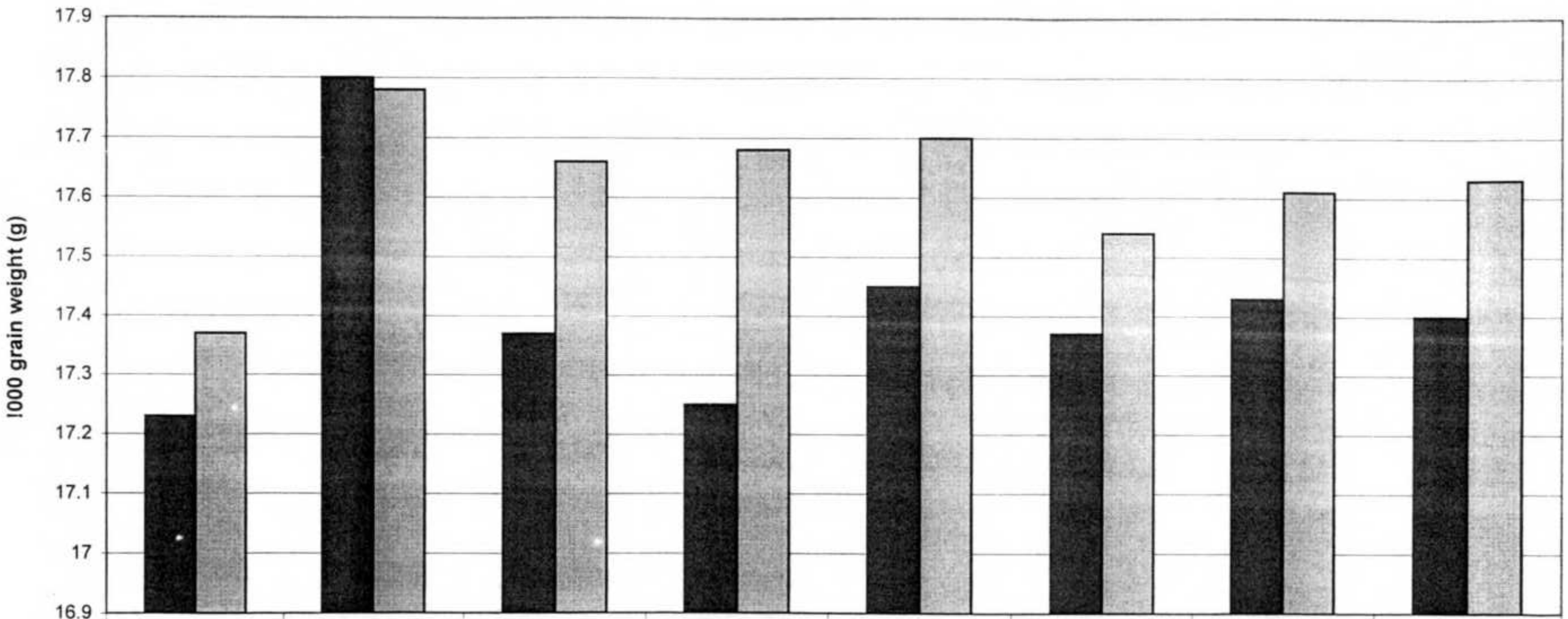
Fig.25 Effect of age of seedlings, plant population and nitrogen levels on straw yield (kg/ha)

5.13. **Test weight (1000 grain weight)** (Fig.26)

There was not much variation in 1000 grain weight due to age of seedlings (planting of either young seedlings or old seedlings of 46 days), increase of plant population, decrease of nitrogen levels and the various interaction effects between age of seedlings, plant population and nitrogen levels. This is ascribed to the genetic character of the variety. The results indicated that agronomic factors did not influence the test weight significantly. This might be due to the reason that test weight is mostly decided by the genotype of the variety and not by management practices. The overall 1000 grain weight was slightly higher during late *Thaladi* season as compared to late *Samba* season in all the treatments.

5.14. Plant uptake of NPK at harvest stage

The uptake of N, P and K did not vary due to various treatments during both the seasons (Table 55, 56 and 57). This revealed that there was no significant difference in uptake of nutrients rice crop due to planting of either young seedlings or old seedlings. Similarly, the uptake of nutrients did not increase with increased plant population. Reduction in nitrogen levels by 25 per cent also did not reduce the NPK uptake significantly. This has only shown that *I.W. Ponni* is a low fertilizer responsive cultivar and even with lesser dose of nitrogen, it could manage to produce more grain yields, probably due to its high nitrogen use efficiency because of better rooting characteristics as well as its better foraging effect to tap more nutrients from larger volume of soil. The overall NPK uptake was higher in late *Thaladi* season than in late *Samba* season. This was due to higher DMP and total biological yield in view of favourable climatic conditions prevailed during the cropping period of late *Thaladi* season. Variations in nitrogen uptake due to seasonal variation was reported by Janaki and Thiyagarajan (2002). They observed low uptake of nitrogen due to low temperature prevailed during crop growth period, and higher nitrogen uptake due to higher temperature and more sunshine hours prevailed during the cropping period.



	25days old	32days old	39days old	46days old	50 hills m-2	66 hills m-2	100% N	75% N
■ LATE SAMBA	17.23	17.8	17.37	17.25	17.45	17.37	17.43	17.4
□ LATE THALADI	17.37	17.78	17.66	17.68	17.7	17.54	17.61	17.63

Treatments

Fig. 26 Effect of age of seedlings, plant population and nitrogen levels on 1000 grain weight (g)

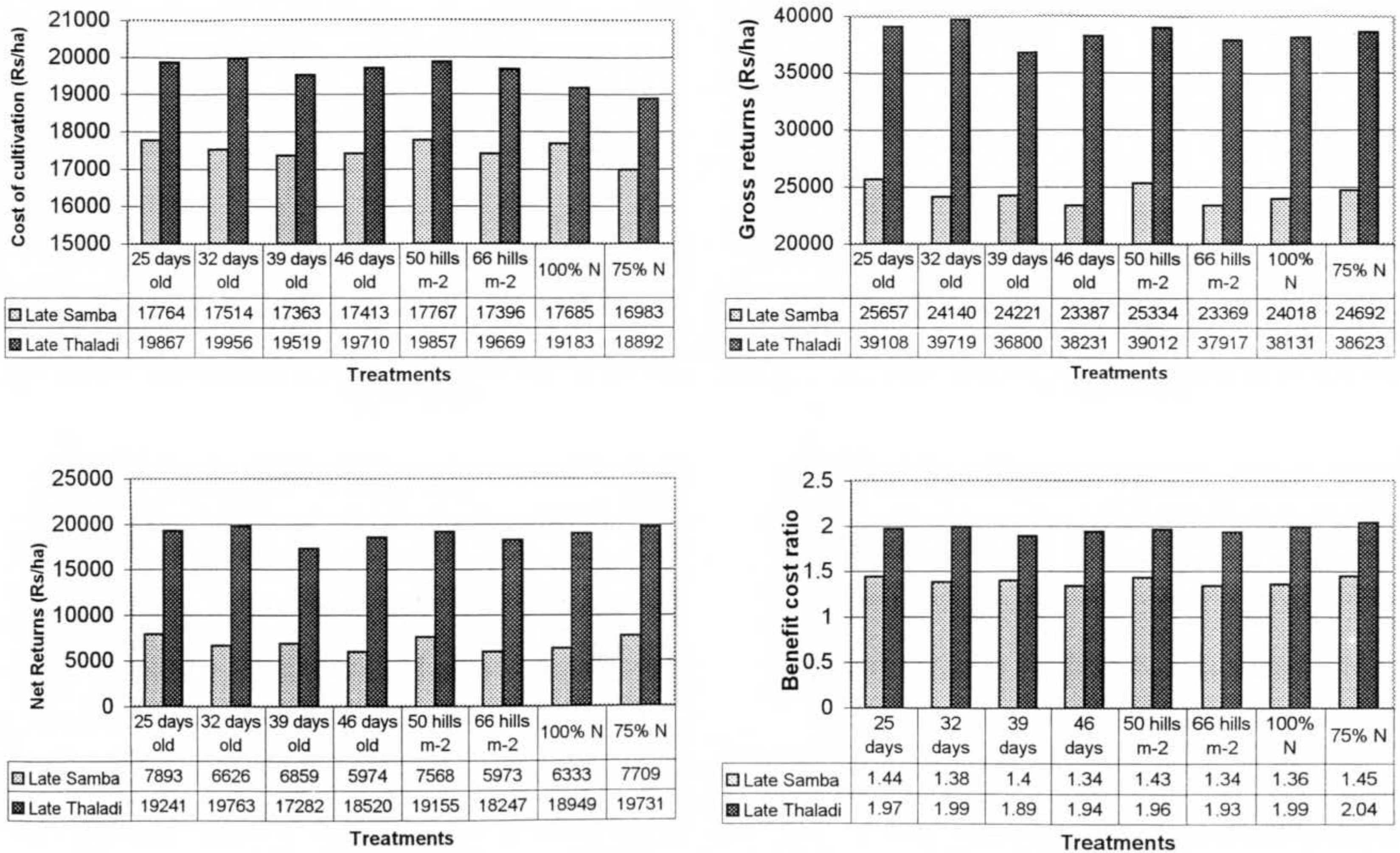
5.15. Post harvest soil NPK

The post harvest available N, P and K did not vary significantly due to various treatments during both the seasons as compared to preplant NPK status of soil. This indicated that the present level of fertilizer application is sufficient to meet the crop uptake and hence, the soil fertility is not affected much.

5.16. Economics (Fig.27)

The cost of cultivation was the highest when 25 days old seedlings was planted at 50 hills m^{-2} with 100 per cent nitrogen (Rs. 18151 ha^{-1}) during late *Samba* season (Table 61) and the cost of cultivation for the same treatment was the highest during late *Thaladi* season (Rs. 20254 ha^{-1}). Of the total cost of cultivation during late *Samba* season, the cost of manures and fertilizers (24.10%), harvesting (22.13%) and transplanting (17.08%) accounted for 63.31 per cent. During late *Thaladi* season the cost of harvesting (30.21%), manures and fertilizers (21.61%) and transplanting (15.13%) accounted for 67.13 per cent of the total cultivation costs (Appendix 3). The lesser share of cost of harvest during late *Samba* season (22.13%) and higher share of cost of harvest during late *Thaladi* season (30.21%) was due to the payment of wages in terms of kind (paddy grains). The existing practice at Karaikal region is that the wages for harvest is fixed as one sixth of the grain yield. When the wages in the form of grain were converted into monetary values, the cost of harvest increases when the crop yield increases in late *Thaladi* season.

The gross returns, net returns and benefit cost ratio were high for all the treatments during late *Thaladi* season as compared to late *Samba* season. Planting of 25 days old seedlings at 50 hills m^{-2} with 100 per cent nitrogen gave the highest gross return, net return and benefit cost ratio during late *Samba* season. But during late *Thaladi* season planting of 25 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen gave the highest gross return, net return and benefit cost ratio. The overall gross return, net return and benefit cost ratio were high during late *Thaladi* season as compared to late *Samba* season. This was mainly due to higher grain yield during late *Thaladi* season as compared to late *Samba* season.



	25 days old	32 days old	39 days old	46 days old	50 hills m-2	66 hills m-2	100% N	75% N
Late Samba	17764	17514	17363	17413	17767	17396	17685	16983
Late Thaladi	19867	19956	19519	19710	19857	19669	19183	18892

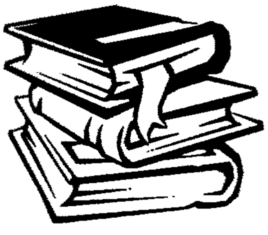
	25 days old	32 days old	39 days old	46 days old	50 hills m-2	66 hills m-2	100% N	75% N
Late Samba	25657	24140	24221	23387	25334	23369	24018	24692
Late Thaladi	39108	39719	36800	38231	39012	37917	38131	38623

	25 days old	32 days old	39 days old	46 days old	50 hills m-2	66 hills m-2	100% N	75% N
Late Samba	7893	6626	6859	5974	7568	5973	6333	7709
Late Thaladi	19241	19763	17282	18520	19155	18247	18949	19731

	25 days	32 days	39 days	46 days	50 hills m-2	66 hills m-2	100% N	75% N
Late Samba	1.44	1.38	1.4	1.34	1.43	1.34	1.36	1.45
Late Thaladi	1.97	1.99	1.89	1.94	1.96	1.93	1.99	2.04

Fig.27 Economics of I.W.Ponni rice variety under various treatments

During late *Samba* season, there was an yield reduction of 156 kg ha^{-1} due to application of 75 per cent nitrogen as compared to 100 per cent nitrogen with 25 days old seedlings at 50 hills m^{-2} (Table 48). The highest grain yield of 3523 kg ha^{-1} was obtained due to planting of 25 days old seedlings at 50 hills m^{-2} with 100 per cent nitrogen. But the same 25 days old seedlings at same population with 75 per cent nitrogen produced 3367 kg ha^{-1}. However, during late *Thaladi* season, there was an increase in grain yield by 186 kg ha^{-1}due to application of 75 per cent nitrogen as compared to 100 per cent nitrogen when planted with 25 days old seedlings at 50 hills m^{-2}. The mean of two seasons resulted in 30 kg ha^{-1} higher grain yield due to 75 per cent nitrogen application. Hence, application of 75 per cent of recommended nitrogen is more economical considering the additional cost of 25 per cent nitrogen. Similarly considering all the treatments, the overall net return was higher due to application of 75 per cent nitrogen (Rs.19731 ha^{-1}) than application of 100 per cent nitrogen (Rs.18949 ha^{-1}) during late *Samba* season. The overall benefit cost ratio at 75 per cent nitrogen were 1.45 and 2.04, respectively during late *Samba* and late *Thaladi* seasons and application of 100 per cent nitrogen gave benefit cost ratio of 1.36 and 1.99, respectively during late *Samba* and late *Thaladi* seasons (Table 61)



SUMMARY AND CONCLUSION

CHAPTER 6

SUMMARY AND CONCLUSION

Field experiments were conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal during late *Samba* and late *Thaladi* seasons coinciding with *Rabi* season during 2001-2002 to study "Agronomic management of aged seedlings of Improved *White Ponni* rice variety for karaikal region" with an objective to find out the effect of aged seedlings, plant population levels, nitrogen levels and their interaction on the growth and yield of *I.W.Ponni* rice variety in Karaikal region. The experiments were laid out in split plot design with three replications. A combination of four ages of seedlings (25, 32, 39 and 46 days old) and two plant population levels (50 and 66 hills m^{-2}) formed the mainplot treatments and two levels of nitrogen (100% and 75% recommended nitrogen days old seedlings) formed the subplot treatments.

Observations were made on the growth characters, yield attributes, grain and straw yield, uptake of nutrients and post harvest available soil nutrients. Economics was worked out for each treatment. The results and conclusions drawn from the study are summarized hereunder.

Planting of young seedlings (25 days to 32 days old) was found to give taller plants throughout the crop period than planting of aged seedlings (39 to 46 days old) during late *Samba* season. Similar trend was observed during late *Thaladi* season at maximum tillering and panicle initiation stages but at harvest stage the plant height did not vary due to planting of seedlings of different ages. The plant height was not influenced either by planting with recommended plant population (50 hills m^{-2}) or with 133 per cent plant population (66 hills m^{-2}) during both the seasons. During late *Samba* season, recommended dose of 100 per cent nitrogen (150 kg ha^{-1}) resulted in taller plants than applications of 75 per cent recommended dose of nitrogen (112.5 kg ha^{-1}) in maximum tillering stage and at harvest stage. But, during late *Thaladi* season, there was no significant difference in plant height due to nitrogen levels. (100 and 75%N). The overall plant height was high in all the treatments during late *Thaladi* season as observed at harvest stage. The interaction effect between age and nitrogen and between population and nitrogen recorded significantly higher plant height during late *Samba* season at harvest stage. At all ages of seedlings, except 32 days old seedlings, 100 per cent nitrogen was found to give taller plants than 75 per cent nitrogen. At both the levels of nitrogen, young seedlings (25 to 32 days old) produced taller plants than 39 and 46 days old seedlings. Similarly, at recommended plant population, 100 per cent nitrogen gave taller plants than 75 per cent nitrogen. At higher plant population (66 hills m^{-2}) both the levels of nitrogen gave comparably taller plants. All ages of seedlings except 32 days old, produced taller plants and were comparable at both the levels of nitrogen. At both the levels of nitrogen, younger seedlings gave taller plants than aged seedlings. However, interaction effects did not show significance on plant height at harvest stage.

The number of leaves $tiller^{-1}$ was influenced by age of seedlings only at maximum tillering stage that too during late *Samba* season. Planting of 46 days old seedlings gave more number of leaves $tiller^{-1}$ than 25,32 and 39 days old seedlings. However, with advancement of age of the crop, age of seedlings did not influence the number of leaves $tiller^{-1}$ significantly as observed at panicle initiation stage. During late *Thaladi* season, the age of seedlings did not have significant effect on the number of leaves $tiller^{-1}$ at both the stages of observation (maximum tillering and panicle initiation). The plant population did not affect the number of leaves $tiller^{-1}$ during both the stages and in both the seasons. The nitrogen level was found to influence the number of leaves $tiller^{-1}$ during late *Samba* season only at maximum tillering stage, with more number of leaves $tiller^{-1}$ at 100 per cent nitrogen than at 75 per cent nitrogen. However, this significance due to nitrogen levels did not last long and it became insignificant at panicle initiation stage. During late *Thaladi* season the nitrogen levels did not have significant effect on number of leaves $tiller^{-1}$ during both the stages. Similarly the various interaction effects did not influence the number of leaves $tiller^{-1}$ significantly as observed at maximum tillering and panicle initiation stages during both the seasons.

The leaf area index was not significantly affected due to age of seedlings, plant population, nitrogen levels and their interaction during late *Samba* season both at maximum tillering and panicle initiation stage. However, during late *Thaladi* season, age of seedlings as well as plant populations were found to have significant impact on leaf area index both at maximum tillering and panicle initiation stage. Planting of young seedlings (25 to 32 days old) gave more leaf area index than older seedlings (39 to 46 days old) at both the stages (maximum tillering and panicle initiation). At higher plant population of 66 hills m^{-2}, the leaf area index was more at recommended plant population of 50 hills m^{-2} during both the stages (maximum tillering, panicle initiation). The nitrogen levels and other interaction effects did not have any significant impact on leaf area index during both the stages of observation. The pooled analysis also revealed that neither the treatment nor season or their interaction had any significant influence on leaf area index as observed at panicle initiation stage.

The number of tillers $hill^{-1}$ as observed at maximum tillering, panicle initiation and harvest stages were not influenced by age of seedlings during late *Samba* season. Conversely, the age of seedlings was found to affect the number of tillers $hill^{-1}$ during all the three stages in late *Thaladi* season. Planting of young seedlings of 25 to 32 days old produced more number of tillers $hill^{-1}$ than 39 and 46 days as observed during maximum tillering, panicle initiation and harvest stages. The plant population was found to affect the number of tillers $hill^{-1}$, with more number of tillers $hill^{-1}$ at recommended plant population of 50 hills m^{-2} than at 133 per cent higher plant population of 66 hills m^{-2} as observed at maximum tillering, panicle initiation and harvest stages during late *Samba* season. However, the plant population did not affect the number of tillers $hill^{-1}$ throughout the crop period as observed during late *Thaladi* season. Except at maximum tillering stage in late *Samba* season, the nitrogen levels did not affect the number of tillers $hill^{-1}$ during both the seasons as observed at maximum tillering, panicle initiation and harvest stages. The number of tillers $hill^{-1}$ at maximum tillering was more with 100 per cent nitrogen than at 75 per cent nitrogen and this difference vanished with the advancement of crop growth till harvest during late *Samba* season.

The dry matter production was affected by various treatments during maximum tillering stage in late *Samba* season and during maximum tillering and panicle initiation stages in late *Thaladi* season. However, the dry matter production was not affected significantly by age of seedlings, plant population, nitrogen levels and their interaction effects as observed at harvest stage during both the seasons.

The pooled analysis of the dry matter production revealed the seasonal effect on dry matter production as observed at maximum tillering, panicle initiation and harvest stages. The higher dry matter production of 11110 kg ha^{-1} was obtained in late *Thaladi* season and the lowest dry matter of 7759 kg ha^{-1} was obtained in late *Samba* season at harvest stage.

The root volume and total root length per hill did not vary significantly due to age of seedlings during late *Samba* season. However, during late *Thaladi* season both root volume and total root length hill^{-1} were increased due to planting of young seedlings of 25 and 32 days as compared to 39 and 46 days old aged seedlings as observed during maximum tillering stage. The plant population influenced both root volume and total root length hill^{-1} significantly during late *Samba* season. Recommended plant population of 50 hills m^{-2} had more root volume and total root length hill^{-1} than that of 133 per cent increased plant population with 66 hills m^{-2} during late *Samba* season at maximum tillering stage. On the contrary, the root volume was influenced by plant population during late *Thaladi* season. However, the total root length hill^{-1} was affected significantly, with 133 per cent higher plant population

The number of productive tillers hill^{-1} did not vary due to planting of seedlings of different ages during late *Samba* season. But during late *Thaladi* season, young seedlings of 25 and 32 days old produced more number of productive tillers hill^{-1} than 39 and 46 days. The plant population was found to influence the number of productive tillers hill^{-1} with more number of productive tillers hill^{-1} at 50 hills m^{-2} (6.53) than at 66 hills m^{-2} (5.52). However, plant population did not affect significantly the number of productive tillers hill^{-1} during late *Thaladi* season. The nitrogen levels as well as the various interaction effects did not affect significantly the number of productive tillers hill^{-1} during both the seasons. Pooled analysis revealed that neither the treatment nor the seasons had significant impact on number of productive tillers hill^{-1}. The interaction effect between season and treatment revealed that during late *Samba* season, planting of 25 days old seedlings at recommended plant population with 100 per cent nitrogen gave higher number of productive tillers hill^{-1} which was on par with that of 39 and 46 days old seedlings at 50 hills m^{-2} with 100 per cent nitrogen. During late *Thaladi* season, 32 days old seedling with 50 hills m^{-2} at 75 per cent nitrogen gave the highest number of productive tillers $hill^{-1}$ and was on par with 25 days old seedlings at both the levels of plant population and nitrogen.

The number of panicles m^{-2} did not vary due to age to seedlings in late *Samba* season. However, during late *Thaladi* season, planting of young seedlings of 25 to 32 days old gave more number of panicles m^{-2} than planting of 39 and 46 days. Higher plant population of 66 hills m^{-2} produced more number of panicles m^{-2} during both the seasons (343 and 345 number of panicles m^{-2}, respectively for late *Samba* and late *Thaladi* seasons) than planting at recommended plant population of 50 hills m^{-2} (303 and 305 number of panicles m^{-2}, respectively). The nitrogen level as well as the other interactions did not have any significant impact on the number of panicles m^{-2} during both the seasons. Pooled analysis revealed that both the treatment and the seasonal effect did not affect the number of panicles m^{-2}. The interaction effect between season and treatment was significant which revealed that during late *Samba* season, planting of 46 days old seedlings at both the levels of plant population and nitrogen produced higher number of panicles m^{-2} and was on par with 39 days old seedlings at higher plant population of 66 hills m^{-2} at both the levels of nitrogen. During late *Thaladi* season, planting of 25 days old seedlings at higher plant population at both the levels of nitrogen produced more number of panicles m^{-2}.

The panicle length was improved considerably by planting young seedlings of 25,32 and 39 days old as compared to planting of 46 days old seedlings during late *Samba* season. However, the age of seedlings did not affect the panicle length during late *Thaladi* season. The plant population, nitrogen levels and the various interaction effects did not affect the panicle length during both the seasons. Pooled analysis revealed the significance of seasonal effect on panicle length. Longer panicles were obtained during late *Thaladi* season (23.68 cm) and shorter panicles were produced during late *Samba* season (20.98 cm).

The panicle weight was affected by age of seedlings during late *Samba* season. Planting of young seedlings gave more panicle weight than planting of old seedlings. However, during late *Thaladi* season, the age of seedlings did not affect the panicle weight. Recommended plant population of 50 hills m^{-2} produced heavy panicles (1.88g) and increased plant population at 66 hills m^{-2} produced light panicle (1.70g). However, plant population did not have significant impact on panicle weight during late *Thaladi* season. The nitrogen level as well as other interaction effect did not have any significant impact on panicle weight during both the seasons. Pooled analysis indicated the seasonal impact on panicle weight. Heavier panicles averaged over all the treatments were obtained during late *Thaladi* season (2.80g) and lighter panicles were produced in all the treatments during late *Samba* season (1.79g).

The age of seedlings did not have significant effect on the number of filled grains $panicle^{-1}$ during both the seasons. Recommended plant population of 50 hills m^{-2} produced more number of filled grains $panicle^{-1}$ (91.32). However, the number of filled grains $panicle^{-1}$ was found to decrease (79.08) due to increase in plant population (66 hills m^{-2}) during late *Samba* season. The plant population did not affect the number of filled grains $panicle^{-1}$ during late *Thaladi* season. The nitrogen levels and the various interaction effects did not have significant effect on number of filled grains $panicle^{-1}$. The number of ill filled grains $panicle^{-1}$ as well as the sterility percentage was not affected due to various treatments during both the seasons.

The grain yield was not affected significantly due to age of seedlings, plant population, nitrogen levels and other interaction effects during late *Samba* season. However, during late *Thaladi* season planting of young seedlings of 25 to 32 days old were found to produce higher grain yields (5136 and 5264 kg ha^{-1}, respectively) than planting of 39 and 46 days old seedlings (4880 and 5048 kg ha^{-1}, respectively). The plant population, nitrogen levels and other interaction effects did not affect the grain yield significantly during late *Thaladi* season. Pooled analysis of the grain yield revealed the significant effect of the season on the grain yield. The overall average yield of various treatments was higher during late *Thaladi* season (5082 kg ha^{-1}) than in late *Samba* season (3161 kg ha^{-1}).

The straw yield was not influenced significantly due to age of seedlings, plant population, nitrogen levels and other interaction effects during both the seasons. Pooled analysis revealed the seasonal impact on the straw yield. During late *Thaladi* season, the overall average yield of straw was higher (6028 kg ha^{-1}) than that of late *Thaladi* season (4562 kg ha^{-1}).

The harvest index did not vary during both the seasons due to age of seedlings, plant population, nitrogen levels and various interaction effects. Test weight did not vary significantly due to various treatments during both the seasons. The average 1000 grain weight ranged from 16.62 to 18.63g for various treatments.

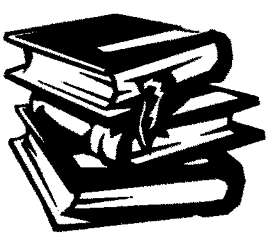
The uptake of N, P and K by the crop did not vary due to various treatments during both the seasons. The nitrogen uptake for the two seasons ranged from 76.41 to 109.77 kg ha^{-1} and from108.40 to 148.29 kg ha^{-1}, the phosphorus uptake ranged from 9.14 to 10.39 kg ha^{-1} and from 10.14 to 13.85 kg ha^{-1} and the potassium uptake ranged from 94.93 to 122.10 kg ha^{-1} and from148.09 to 188.38 kg ha^{-1}, respectively for late *Samba* and late *Thaladi* seasons. The overall uptake of NPK was higher during late *Thaladi* season than in late *Samba* season.

The post harvest available N, P and K status did not vary due to various treatments and there was not much variation in depletion of N, P and K as compared to preharvest available NPK due to the uptake by crop under various treatments.

Planting of 25 days old seedlings at 50 hills m^{-2} with 100 per cent recommended nitrogen (150 kg N ha^{-1}) gave the highest gross return, net return and benefit cost ratio during late *Samba* season. Similarly, planting 25 days old seedlings at 50 hills m^{-2} with 75 per cent recommended nitrogen (112.5 kg N ha^{-1}) gave the highest gross return, net return and benefit cost ratio during the late *Thaladi* season. Irrespective of the plant population and age of seedlings, application of 75 per cent nitrogen gave higher gross return (Rs.24692 and Rs.38623, respectively during late *Samba* and late *Thaladi* seasons), net return (Rs.7709 and Rs.19731, respectively during late *Samba* and late *Thaladi* seasons) and benefit cost ratio (1.45 and 2.04, respectively during late *Samba* and late *Thaladi* seasons) than application of 100 per cent nitrogen (gross return of Rs.24018 and Rs.38131, net return of Rs.6333 and Rs.18949 and benefit cost ratio of 1.36 and 1.99 respectively, during late *Samba* and late *Thaladi* seasons). Similarly, irrespective of age of seedlings and nitrogen levels, planting of recommended plant population at 50 hills m^{-2} (20 x 10cm spacing) resulted in higher gross return (Rs.25334 and Rs.39012, respectively during late *Samba* and late *Thaladi* seasons), net return (Rs.7567 and Rs.19155, respectively during late

Samba and late *Thaladi* seasons) and benefit cost ratio (1.43 and 1.96 respectively, during late *Samba* and late *Thaladi* seasons) than planting of higher plant population at 133 per cent with 66 hills m^{-2} (gross return of Rs.23369 and Rs.37917, net return of Rs.5973 and Rs.18247 and benefit cost ratio of 1.34 and 1.93 respectively, during late *Samba* and late *Thaladi* seasons).

It is concluded that planting of Improved *White Ponni* during late *Samba* season (1st October to 31st October) with 25 days old seedlings at 50 hills m^{-2} with 100 per cent recommended nitrogen (150 kg ha^{-1}) is economical. But during late *Thaladi* season, planting of 25 days old seedlings at 50 hills m^{-2} with 75 per cent nitrogen (112.5 kg ha^{-1}) is economical with a saving of 37.5 kg N ha^{-1}. During late *Thaladi* season planting can be taken up even with 46 days old seedlings as the reduction in grain yield was very minimum (88 kg ha^{-1}).



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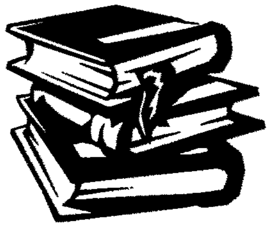

APPENDICES

Appendix 1. Effect of age of seedlings, plant population and nitrogen levels on agronomic nitrogen use efficiency of *I.W.Ponni* rice variety during late *Samba* and late *Thaladi* seasons.

Treatments	Late Samba	Late Thaladi	Mean
$A_{25}P_{50}N_{100}$	23.49	35.79	29.63
$A_{25}P_{50}N_{75}$	29.93	49.37	38.76
$A_{25}P_{66}N_{100}$	20.19	32.65	26.42
$A_{25}P_{66}N_{75}$	30.62	43.78	37.20
$A_{32}P_{50}N_{100}$	20.02	34.61	27.31
$A_{32}P_{50}N_{75}$	27.76	47.31	37.54
$A_{32}P_{66}N_{100}$	19.93	35.48	27.71
$A_{32}P_{66}N_{75}$	29.96	46.40	38.18
$A_{39}P_{50}N_{100}$	22.67	32.96	27.82
$A_{39}P_{50}N_{75}$	29.12	42.52	35.82
$A_{39}P_{66}N_{100}$	18.46	32.11	25.29
$A_{39}P_{66}N_{75}$	27.96	44.23	36.10
$A_{46}P_{50}N_{100}$	23.14	33.19	28.17
$A_{46}P_{50}N_{75}$	29.04	46.85	37.95
$A_{46}P_{66}N_{100}$	18.20	32.44	25.32
$A_{46}P_{66}N_{75}$	23.69	45.17	34.43
Mean	24.64	39.68	32.16

A_{25} – 25 days old seedlings
A_{32} – 32 days old seedlings
A_{39} – 39 days old seedlings
A_{46} – 46 days old seedlings
P_{50} – 50 hills m^{-2}
P_{66} – 66 hills m^{-2}
N_{100} – 100% recommended N
N_{75} – 75% recommended N

Appendix 2. Cost of cultivation of *I.W.Ponni* rice variety (excluding harvest costs*)

Sl. No	Particulars	A type: Man (Rs. 60)	B type: Woman (Rs. 50)	Total cost (Rs)
1.	**Nursery preparation (20 cents ha^{-1})**			
	1. Preparatory cultivation			
	(i) Puddling with power tiller (Rs. 1500 ha^{-1}) – for 20 cents			120.00
	(ii) Trimming, plastering and levelling	1		60.00
				180.00
	2. Seeds and sowing			
	(i) Cost of seeds @ 40 kg ha^{-1} – Rs. 10 kg^{-1} of seeds			400.00
	(ii) Seed treatment with Carbendazim @ 2 g kg^{-1} for 80 g @ Rs. 74/ 100 g			59.20
	(iii) Sowing and incubation	1.5		90.00
				549.20
	3. Manures and fertilizers			
	(i) Nursery manuring – FYM 1t /20 cents @ Rs.100 ton^{-1}			100.00
	(ii) Application of DAP @ 2 kg $cent^{-1}$, for 40 kg @ Rs.435 / 50 kg			348.00
	(iii) Application cost	0.5		30.00
				478.00

Sl. No	Particulars	A type: Man (Rs. 60)	B type: Woman (Rs. 50)	Total cost (Rs)
	4. Plant protection			
	(i) One spray of monocrotophos @ 40 ml- Rs. 38 / 100 ml			15.20
	(ii) Application cost	0.5		30.00
				45.20
	5. Irrigation and guidance	2		120.00
2.	**Main field preparation**			
	1. Land preparation			
	(i) Puddling by tractor @ Rs. 1125 ha^{-1}			1125.00
	(ii) Trimming, plastering, levelling and digging the corners	10		600.00
				1725.00
	2. Manures and fertilizers			
	(I) Farm yard manure – 12.5 t ha^{-1} @ Rs. 100 ton^{-1}			1250.00
	(ii) Spreading	4		240.00
	(iii) cost of fertilizers			
	(a). For 100 per cent recommended dose of nitrogen – 150:50:50 kg NPK ha^{-1}			
	Urea – 326 kg ha^{-1} @ Rs. 4.40 kg^{-1}			1434.40
	Single super phosphate – 312.5 kg ha^{-1} @ Rs. 3.00 kg^{-1}			937.50

Sl. No	Particulars	A type: Man (Rs. 60)	B type: Woman (Rs. 50)	Total cost (Rs)
	Muriate of Potash – 83.3 kg ha^{-1} @ Rs. 4.00 kg^{-1}			333.20
	(b). For 75 per cent recommended dose of nitrogen – 112.5:50:50 kg NPK ha^{-1}			1076.10
	Urea – 244.57 kg ha^{-1} @ Rs. 4.40 kg^{-1}			
	Single super phosphate – 312.5 kg ha^{-1} @ Rs. 3.00 kg^{-1}			937.50
	Muriate of Potash – 83.3 kg ha^{-1} @ Rs. 4.00 kg^{-1}			333.20
	(iv) Application of fertilizer	3		180.00
	Total (a)			4375.10
	Total (b)			4016.80
3.	**Transplanting**			
	(i) Pulling out of seedling, transport and distribution	15		900.00
	(ii) Transplanting		44	2250.00
				3100.00
4.	**After cultivation – Weeding**			
	(i) Butachlor – 2.5 litre ha^{-1} @ Rs. 212.00 $litre^{-1}$			520.00
	(ii) Application cost	1		60.00
	(iii) Hand weeding		30	1500.00
				2080.00

Sl. No	Particulars	A type: Man (Rs. 60)	B type: Woman (Rs. 50)	Total cost (Rs)
5.	**Plant protection**			
	(i) One spray with Monocrotophos - 1000 ml ha^{-1} @ Rs. 380.00 / litre			380.00
	(ii) One spray with Phospomidon – 300 ml ha^{-1} @ Rs. 54.00 / 100 ml			162.00
	(iii) Spraying cost	2	2	220.00
				762.00
6.	**Irrigation and guidance**	12		720.00
	Total cost of cultivation excluding cost of harvest			
	1. At 100 per cent nitrogen			14134.50
	2. At 75 per cent nitrogen			13776.20

*The cost of harvest varies with the grain yield at each treatment since in Karaikal region, the wages for the harvest is fixed as one sixth of the grain yield and the quantity of grains given as wages is converted into monetary values based on the market price to arrive at the cost of harvest.

Appendix 3a. Percentage share of various costs to the total cost of cultivation of *I.W.Ponni* rice variety under various treatments during late *Samba* season.

Treatment	Nursery cost	Main field preparation	Manures & fertilizers	Transplanting	Plant protection	After cultivation	Irrigation	Harvest
$A_{25}P_{50}N_{100}$	7.56	9.51	24.10	17.08	4.19	11.46	3.97	22.13
$A_{25}P_{50}N_{75}$	7.81	9.81	22.85	17.64	4.12	11.83	4.10	21.84
$A_{25}P_{66}N_{100}$	7.80	9.81	24.88	17.63	4.33	11.83	4.09	19.63
$A_{25}P_{66}N_{75}$	7.75	9.75	22.69	17.51	4.30	11.75	4.07	22.18
$A_{32}P_{50}N_{100}$	7.82	9.81	24.92	17.66	4.34	11.85	4.10	19.50
$A_{32}P_{50}N_{75}$	7.92	9.95	23.17	17.88	4.40	11.99	4.15	20.54
$A_{32}P_{66}N_{100}$	7.82	9.84	24.94	17.67	4.34	11.86	4.01	19.43
$A_{32}P_{66}N_{75}$	7.79	9.79	22.79	17.60	4.32	11.81	4.09	21.81
$A_{39}P_{50}N_{100}$	7.62	9.59	24.29	17.21	4.23	11.55	3.99	21.52
$A_{39}P_{50}N_{75}$	7.84	9.85	22.94	17.70	4.35	11.88	4.11	21.33
$A_{39}P_{66}N_{100}$	7.94	9.97	25.30	17.93	4.41	12.03	4.16	18.26
$A_{39}P_{66}N_{75}$	7.90	9.94	23.13	17.85	4.39	11.98	4.15	20.66
$A_{46}P_{50}N_{100}$	7.59	9.53	24.18	17.14	14.21	11.50	3.98	21.87
$A_{46}P_{50}N_{75}$	7.84	9.87	22.95	17.71	4.35	11.89	4.11	21.28
$A_{46}P_{66}N_{100}$	7.96	10.00	25.37	17.97	7.43	12.06	4.17	18.04
$A_{46}P_{66}N_{75}$	8.16	10.26	23.89	18.44	4.53	12.37	4.28	18.07

Appendix 3b. Percentage share of various costs to the total cost of cultivation of *I.W.Ponni* rice variety under various treatments during late *Thaladi* season.

Treatment	Nursery cost	Main field preparation	Manures & fertilizers	Transplanting	Plant protection	After cultivation	Irrigation	Harvest
$A_{25}P_{50}N_{100}$	6.78	8.51	21.61	15.13	3.76	10.27	3.55	30.21
$A_{25}P_{50}N_{75}$	6.83	8.57	19.98	15.42	3.79	10.34	3.58	31.49
$A_{25}P_{66}N_{100}$	6.96	8.75	22.19	15.73	3.86	10.55	3.65	28.31
$A_{25}P_{66}N_{75}$	7.08	8.90	20.72	15.99	3.92	10.73	3.71	28.95
$A_{32}P_{50}N_{100}$	6.84	8.60	21.82	15.47	3.80	10.37	3.59	29.51
$A_{32}P_{50}N_{75}$	6.92	8.69	20.24	15.62	3.85	10.48	3.63	30.57
$A_{32}P_{66}N_{100}$	6.79	8.54	21.66	15.35	3.77	10.30	3.56	30.03
$A_{32}P_{66}N_{75}$	6.96	8.75	20.36	15.71	3.86	10.54	3.65	30.17
$A_{39}P_{50}N_{100}$	6.94	8.73	22.13	15.68	3.85	10.52	3.64	28.51
$A_{39}P_{50}N_{75}$	7.14	8.97	20.89	16.12	3.96	10.82	3.74	28.36
$A_{39}P_{66}N_{100}$	6.99	8.79	22.29	15.80	3.88	10.60	3.67	27.98
$A_{39}P_{66}N_{75}$	7.06	8.87	20.64	15.94	3.92	10.70	3.70	29.17
$A_{46}P_{50}N_{100}$	6.93	8.71	22.08	15.65	3.85	10.50	3.63	28.65
$A_{46}P_{50}N_{75}$	6.94	8.72	20.30	15.67	3.85	10.51	3.64	30.37
$A_{46}P_{66}N_{100}$	6.97	8.76	22.24	15.75	3.87	10.57	3.66	28.18
$A_{46}P_{66}N_{75}$	7.01	8.82	20.53	15.86	3.89	10.63	3.68	29.58

Appendix 4. Sale price of *I.W.Ponni* rice variety round the year at Karaikal

Months	Prices
October, 2001	618.28
November, 2001	625.31
December, 2001	632.48
January, 2002	631.58
February, 2002	789.47
March, 2002	754.38
April, 2002	758.77
May, 2002	789.47
June, 2002	790.20
July, 2002	859.69
August, 2002	877.19
September, 2002	614.04

Source: Directorate of Economics and Statistics, Regional Office, Karaikal, Government of Pondicherry.

Appendix 5. Weather parameters prevailed at three stages of the crop during late *Samba* season

Period	Maximum Temperature °C	Minimum temperature °C	Relative Humidity (7.12 hrs)	Sunshine hours (Total)	Total rainfall (mm)
I. Maximum tillering stage					
25 days old seedlings (41-45 std week)	31.88	24.54	91.00	180.17	390.75
32 days old seedlings (42-46 std week)	31.14	24.36	92.20	159.90	448.75
39 days old seedlings (43-47 std week)	30.40	23.98	93.00	148.60	486.00
46 days old seedlings (44-48 std week)	29.94	23.74	93.40	156.10	369.75
II. Panicle initiation stage					
25 days old seedlings (46-49 std week)	28.95	22.70	93.40	118.30	223.25
32 days old seedlings (47-50 std week)	28.53	21.68	93.00	146.80	155.75
39 days old seedlings (48-51 std week)	28.15	21.60	92.00	134.70	223.50
46 days old seedlings (49-52 std week)	27.87	21.50	92.00	122.50	526.00
III. Harvest stage					
25 days old seedlings (52-6 std week)	25.19	21.40	93.56	333.20	840.00
32 days old seedlings (51-6 std week)	24.81	21.60	93.75	276.00	840.00
39 days old seedlings (52-6 std week)	24.42	21.44	94.29	259.60	670.50
46 days old seedlings (1-6 std week)	23.93	21.30	94.33	244.90	316.00

Appendix 6. Weather parameters prevailed at three stages of the crop during late *Thaladi* season

Period	Maximum Temperature °C	Minimum temperature °C	Relative Humidity (7.12 hrs)	Sunshine hours (Total)	Total rainfall (mm)
I. Maximum tillering stage					
25 days old seedlings (46-50 std week)	28.84	22.18	93.20	174.50	223.25
32 days old seedlings (47-51 std week)	28.56	21.88	93.60	163.20	325.25
39 days old seedlings (48-52 std week)	28.26	21.75	93.60	149.40	578.00
46 days old seedlings (49-1 std week)	28.14	21.50	93.60	159.60	531.25
II. Panicle initiation stage					
25 days old seedlings (51-3 std week)	27.82	21.54	94.40	168.10	570.50
32 days old seedlings (52-4 std week)	28.36	21.38	94.40	209.00	401.00
39 days old seedlings (1-5 std week)	28.62	21.32	94.40	219.60	276.00
46 days old seedlings (2-6 std week)	28.72	21.26	94.40	227.60	310.75
III. Harvest stage					
25 days old seedlings (4-9 std week)	29.68	21.33	95.33	301.00	269.50
32 days old seedlings (5-10 std week)	29.93	21.25	94.67	316.80	269.50
39 days old seedlings (6-10 std week)	30.18	21.11	94.80	291.50	40.00
46 days old seedlings (7-11 std week)	30.88	21.32	94.40	300.90	0.00

PLATES

Plate 1. Field view of the experimental plot (Late *Samba*)

Plate 2. Field view of the experimental plot (Late *Thaladi*) showing the submergence of the crop planted with 39 days old seedlings which resulted in the lowest grain yield

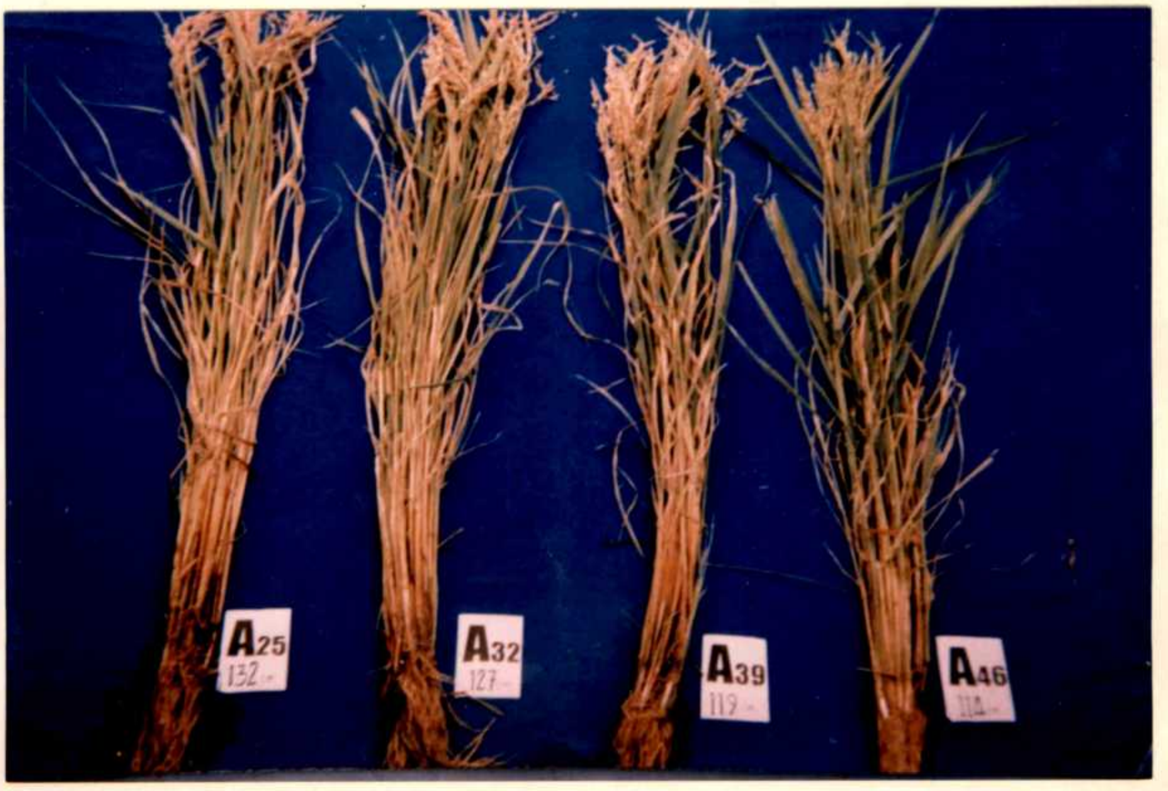

Plate 3. Effect of age of seedlings on plant height at harvest stage

Plate 4. Early maturity of the crop planted with 25 days old seedlings as compared to 46 days old seedlings at same level of plant population and fertilizers (50 hills m^{-2} with 100 % nitrogen)