GENOTYPE - ENVIRONMENT INTERACTION IN NEW PLANT TYPE (NPT) LINES OF RICE (*Oryza sativa* L.)

By

M. MARIMUTHU

THESIS

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Department of Plant Breeding & Genetics

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DECLARATION

I hereby declare that this thesis entitled **"Genotype - Environment interaction in New Plant Type (NPT) lines of rice (*Oryza sativa* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

M. MARIMUTHU

Place : Vellanikkara,

Date : 10·08·2007

CERTIFICATE

Certified that this thesis, entitled **"Genotype - Environment interaction in New Plant Type (NPT) lines of rice (*Oryza sativa* L.)"** is a record of work done independently by **Mr. M. Marimuthu,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Place: Vellanikkara ,

Date: 10-08-2007

Dr. C. R. Elsy
(Chairperson, Advisory Committee)
Assistant Professor (S.S)
Dept. of Plant Breeding &Genetics
College of Horticulture, Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of Mr. **M. Marimuthu**, a candidate for the Degree of **Master of Science in Agriculture** with major in **Plant Breeding & Genetics**, agree that this thesis entitled **Genotype - Environment interaction in New Plant Type (NPT) lines of rice (*Oryza sativa* L.)** may be submitted by Mr. M.Marimuthu, in partial fulfilment of the requirement for the degree.

Dr.C.R.Elsy
(Chairperson, Advisory Committee)
Assistant Professor (S.S)
Department of Plant Breeding and Genetics
College of Horticulture, Vellanikkara

Dr.V.V.Radha krishnan
(Member, Advisory Committee)
Associate Professor and Head
Department of Plant Breeding & Genetics
College of Horticulture, Vellanikkara

Dr.K.T.Presanna Kumari
(Member, Advisory Committee)
Associate Professor
Department of Plant Breeding & Genetics
College of Horticulture, Vellanikkara

Dr.Jose Mathew
(Member, Advisory Committee)
Associate Professor & Head
Cashew Research Station
Madakkathara.

(EXTERNAL EXAMINER)

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M.MARIMUTHU

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DEDICATED TO,

MILLIONS OF RICE FARMERS
&
MY BELOVED PARENTS

INTRODUCTION

INTRODUCTION

Rice is an important cereal crop and is the staple food for more than half of the total population across the world. Rice is grown in 144 countries in the world, in 150 million ha with a production of 608 million tons (Rai, 2006). According to Food & Agricultural Organization, the global rice production must reach 800 million tons from the present 608 million tons of 2005 to meet the demand of 2025 (Swaminathan, 2006). Enhancing the yield potential of rice would be the key to meet the global rice requirement. To achieve the target level, rice varieties with an yield advantage of about 20 percent over widely grown varieties under tropical condition must be developed (Virk *et al.*, 2004). Therefore, the average yield of irrigated rice varieties must increase in tropical rice lands from 5.0 to 8.5 t / ha.

Rice plays a pivotal role in Indian economy and in India, rice is grown in 43 million ha with an annual production of around 89 million tons with a productivity of 2.08 t / ha. Among the rice growing countries, India stands first in area and second in production. It's area and production accounts for 27.5 per cent and 14.5 per cent of the global share respectively. To meet the demands of increasing population and to maintain food self-sufficiency, the present production level of rice in India needs to be increased upto 120 million tons by 2020 (Viraktamath *et al.*, 2006).

Ideotype breeding in rice, called as New Plant Type (NPT) breeding, is aimed to develop rice lines with 20-25 per cent higher productivity than existing improved varieties (IRRI, 1989). The NPT lines developed at IRRI are characterized by less number of tillers (8-10), absence of unproductive tillers, increased biomass, vigorous root system and thick, dark green, erect leaves for better photosynthetic efficiency (Jenning, 1964).

Currently, Kerala is producing less than 25 per cent of its requirement. In Kerala, rice is cultivated in 3.5 lakh ha with a production of 8.6 lakh tons with a productivity of 2.5 t / ha (State Planning Board, 2005). It is more alarming that the area under rice is decreasing year by year. Therefore, there is a need to increase the production and productivity of rice in the state.

Efforts for development of NPT lines at IRRI resulted in the development of lines with a yield potential of 10-12 t / ha (Virk and Khush, 2003). Intense efforts on breeding for NPT lines in China had led to the release of three NPT lines. Directorate of Rice Research (DRR), Hyderabad and few other centers in India, are actively pursuing research on NPT lines ideal for tropical situations.

Till now, no serious effort had been made to evaluate these NPT lines under conditions prevailing in Kerala. Hence, the present attempt was to assess the performance of NPT lines from IRRI, Philippines in Palghat district, Kerala, where there is a consumer preference for white kernel colour. The best lines identified in this study, can be recommended for commercial cultivation and can also be used in future breeding programmes aimed for development of high yielding widely adapted ideotype lines for the state.

Stability in varietal productivity of rice is essential, because relative performance of genotype is not consistant from one environment to another. Hence, the study on G x E interactions helps in the identification of genotypes suitable for wider adaptation / specific environments. Therefore identification of stable genotype is very important for breeding as well as for cultivation purposes.NPT lines developed in other countries and other parts of our country are to be evaluated under Kerala climatic conditions for revealing their yield stability and consumer acceptance. Analysis of multilocation data can help to dissect the Genotype x Environment interaction into different components for assessing the genetic worth of genotypes for specific environments.

Hence, the present investigation on Genotype - Environment interaction in New Plant Type (NPT) lines of rice was carried out with the following objectives:

- To assess the magnitude of genotype - environment interaction on NPT lines over locations in the central zone of Kerala
- To assess the stability of NPT lines over different environments in the central zone of Kerala
- To identify stable and elite NPT lines based on grain yield and its components over locations
- To assess the cooking and milling quality characteristics of NPT rice lines

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Ideotype breeding is a method of crop improvement and used to enhance genetic yield potential through genetic manipulation of individual plant character. The ideotype approach in rice has been introduced by IRRI to improve rice yield potential (Khush, 1995). The goal was to develop New Plant Type lines with a yield potential of 20-25 per cent higher than the existing semi-dwarf rice varieties adopting ideotype breeding. Consequently, NPT lines were developed from many international rice improvement programmes. NPT lines developed by IRRI, popularly termed by the media as "Super Rice", expect to yield 12.5 t per ha (Peng *et al.*, 2004 and Moon and Kang , 2006).

Success of ideotype breeding in China and IRRI suggested that ideotype approach is effective for breaking the yield ceiling of irrigated rice in rice based cropping system. Intensive development and evaluation of NPT lines at IRRI led to the development of many NPT lines with desired characteristics (Khush, 1995).During 1988, about 500 NPT lines had been evaluated in observation trails at IRRI farm (Peng *et al.*, 1999).Chinese rice breeders had released three NPT lines viz., Dianchao-1, Dianchao-2 and Dianchao-3. Another NPT line had been released from Indonesia (Virk *et al.*, 2004).

A brief review of literature on various aspects, related to G x E interaction in New Plant Type lines of rice (*Oryza sativa*.L.), is presented with the following headlines. Wherever the literature is insufficient regarding NPT lines, the information on conventional varieties is presented.

- 2.1 Ideotype Breeding in field crops
  - ⇒ 2.1.1 Ideotype concept
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2.1 Ideotype Breeding in field crops

2.1.1 Ideotype concept

Donald (1968) defined crop ideotype as an idealized plant type with a specific combination of characters favorable for photosynthesis, growth and grain production based on the knowledge of plant and crop physiology.Ideotype breeding, aimed to modify the plant architecture is a time tested strategy to achieve increases in yield potential.Ideotype breeding in cereals such as wheat, rice and sorghum resulted in doubling of yield potential (Donald, 1968 and Chandler, 1969). Donald and Hamblin (1976) proposed three types of ideotypes viz., isolation, competition and crop ideotypes and the specific features of these are presented in Table 1.

In addition, Donald (1968) had proposed several other ideotypes that include traits concerned with specific featutes.For example, market ideotype includes traits like seed colour, seed size, cooking and baking quality etc.since these traits determine the market acceptability of the produce. Similarly, a **climatic ideotype** includes traits important in climatic adaptation like early maturity, thermo period-insensitivity, heat and cold tolerance, drought tolerance, photoperiod-insensitivity etc. Some other types of ideotypes are **edaphic ideotype** with traits of salinity tolerance, mineral toxicity / deficiency tolerance etc. **stress ideotype** of with traits resistance to the concerned abiotic and biotic stresses and **disease / pest ideotype** with traits like resistance to the concerned disease and insect pests etc.

Plant breeders have attempted to enhance yield potential by selecting for individual traits since the beginning of plant breeding .This approach has been broadened to encompass the breeding of model plants or ideotypes (Ramusson, 1987).The best known examples have occurred with wheat and rice. In the 1950s wheat and rice breeders developed highly successful cultivars having short stature with erect leaves (Jennings, 1964 and Reitz *et al.*, 1968).

Gifford *et al.* (1984) reported that attempts to use physiological and biochemical knowledge to develop selection criteria for improvement in genetic yield potential had

Table 1.Characteristic features of isolation, competition and crop ideotypes

Features	Isolation ideotype	Competion ideotype	Crop ideotype
Best performance in	Plants in isolation i.e. space planting	Plants in mixed community. eg., segregation generation	Plants in a dense monoculture. i.e. crop planting.
Performance measured as	Grain yield / plant	Grain yield / plant	Grain yield / plant
Types of plant community in which perform best	Widely-.spaced plants or rows	The segregating generation. and varietal mixtures planted at crop densities	The commercial crops.i.e. plants of a single genotype planted at crop density.
Likelihood of being picked during			
(1) F2 (Space planted; visual or single plant yield)	Quite likely	Less likely	Rather unlikely
(2) Early generation yield tests	Quite low	Very likely	Rather unlikely
(3) Yield test of homozygous and homogenous progenies	Rather unlikely	Rather unlikely	Very likely

been disappointing. Identifying individual traits that enhance yield universally, or even in a relatively limited genetic and climatic situation, had been a difficult task (Crosbie and Mock, 1981 and Wych *et al.*, 1985).

Generally, crop models require two types of inputs such as environmental inputs (weather variables and management options) and physiological inputs (Hunts *et al.*, 1993; White and Hoogenboom,1996 and Marvomatis *et al.*,2001).These parameters were also called as Crop Model Input traits (Yin *et al.*,2000 a).

Given the expectation that crop models based on physiologically sound mechanisms had the potential to identify and integrate crop yield responses to genetic and environmental factors, physiologists and modelers had explored potential uses of crop models in various aspects of breeding:

⇒ To identify main yield determining traits (Yin *et al.*, 2000 b)

⇒ To define optimum selection environments (Aggarwal *et al.*, 1997)

⇒ To optimize single trait values (Setter *et al.*, 1995 and Yin *et al.*, 1997)

⇒ To design ideotypes consisting of multiple traits (Haverkort and Kooman, 1997)

⇒ To assist multiplication testing (Dua *et al.*, 1990) and explain genotype x environment interactions (Mavromatis *et al.*, 2001)

Crop modeling has been considered as a useful tool to assist breeding (Loomis *et al.*, 1979). Shorter *et al.* (1991) proposed collaborative efforts among crop breeders, physiologists and modelers, using models as a framework to integrate Physiology with Plant Breeding. For such, understanding the inheritance of the model parameters is required (Jackson *et al.*, 1996).

Yin *et al.* (2003) proposed an approach of crop model for crop improvement that integrates marker-assisted selection into model-based ideotype framework to support breeding for high crop yield .For this approach to be effective, there is a need to develop crop models that are capable of predicting yield differences among genotypes in a population under various environmental conditions.

2.1.2 Proposed ideotypes in field crops

Ideotypes designed for a number of crops such as rice, wheat, barley, cotton and maize, are reviewed below with specific breeding traits.

2.1.2.1 Wheat

Donald (1968) designed a wheat ideotype, for high grain yields, when grown at high density in a favorable environment for water and nutrient supply. The features of this model are short and strong stem, few small and erect leaves, high harvest index, erect ear awns and a single culm.However, Atsmon and Jacobs (1977) in Israel reported that lines of wheat, which they described as quite similar to the Donald ideotype lines with restricted tillering and gigas characters(large spikes with many kernels,thick,stiff stem and broad thick leaves), had been derived from a North African local cultivar and were used in a breeding programme to give a gigas uniculm line of good yield performance in small plant.

2.1.2.2 Barley

Concept of barley ideotype (Donald, 1979) was barrowed from wheat ideotype (Donald, 1968).This ideotype should have short and strong stem, few small and erect leaves, high harvest index, erect ears, awns and a single culm. Jotun *sdw* genes of semi-dwarf barley lines did not show response of grain yield (Pfund, 1972 and Ali *et al.*, 1978). Subsequently, Ramusson (1987) proposed no change in tillers per m^2, ear numbers per m^2, awn length, leaf length and harvest index from the levels of these traits in the current cultivars like "Morex" and "Robust". Increasing kernel number per head resulted in high grain yields in three of four populations (Lee, 1986), and kernel weight has been associated consistently with high grain yield (Whitaker, 1986).

2.1.2.3 Maize

Mock and Pearce (1975) proposed a maize ideotype (Table 2) that will maximum utilize an optimum production environment. This environment is presumed to include adequate moisture, favourable temperature throughout the growing season, adequate fertility, high plant densities, narrow row spacing and early planting dates.

Table 2. Features of proposed ideotype in maize

Target	Maize ideotype
1.Leaves	⇒ Stiff-vertically oriented leaves above the ear ⇒ Horizontally oriented leaves below the ear (Montieth, 1965 and Duncan *et al.*, 1967) ⇒ Efficient translocation of photosynthate into grain (Simmonds, 1973). ⇒ Maximum photosynthetic efficiency (Curtis *et al.*, 1969 and Domhoff and Shibles, 1970).
2.Ear-Shoot prolificacy	More than one fertile cob, when spaced widely (Bingham, 1967; King *et al.*, 1967 and Duvick, 1974).
3.Anthesis	Short interval between pollen shed and silk emergence (Stinson, 1960; Ellakany and Russell, 1971 and Buren *et al.*, 1974).
4.Size of tassel	Small tassels for lower competition for nutrients with the developing ear as well as less shading of the upper leaves (Chinwuba *et al.*, 1961).
5.Others traits	⇒ Photoperiod-insensitivity (Francis *et al.*,1969). ⇒ Cold tolerance in germinating seeds and young seedlings (Moss *et al.*,1961) ⇒ Long grain filling period and slow leaf senescence (Daynard *et al.*, 1971 and Carter and Poneleit, 1973).

2.1.2.4 Cotton

Ideotypes for *G.hirsutum* have been developed for irrigated and rain fed conditions (Singh, 1998).Several researchers working with various species of cotton have reported the existence of deviant *G.hirsutum* L. plant types having either sympodia bearing 2-5 squares per node (Thadani,1923;Harland,1939;Neely,1942;Silow,1946; Butany and Singh, 1963 and Mithaiwala *et al.*,1974) and deviant *G. barbadense* L. types with sympodia reduced to one internode (Kearney,1930 and Reddy *et al.*,1971), or a combination of both characters (Bhat and Desai,1956).

2.2 Ideotype breeding in rice (*Oryza sativa* L.)

2.2.1 NPT concept

Many rice breeders have been engaged in designing a rice ideotype for achieving a quantum jump in yield (Engledow and Badham, 1923).Jennings (1964) proposed the model of new plant type in rice. Donald (1968) defined crop ideotype as an idealized plant type with a specific combination of characters favorable for photosynthesis, growth and grain production based on the knowledge of plant and crop physiology.

A modest increase in culm diameter was suggested for better yielding, because it was morphogenetically compatable with increasing kernel number and kernel size and lodging resistance (Berdahl *et al.*, 1965 and Schaller *et al.*, 1972).

Plant physiologist suggested an increased photosynthetic efficiency and greater sink capacity as possible approaches to increase yield potentials However, photosynthetic capacity has not resulted in higher grain yield (Yoshida *et al.*, 1972 and Donald *et al.*, 1974).

Yield potential of rice determined by solar radiation at reproductive stage, ear bearing percentage and panicle numbers were largely influenced by total solar radiation. The number of spikelets per unit land area could be achieved either by increasing panicle number or panicle size (Yoshida *et al.*, 1972; Yoshida, 1981 and Takeda, 1984).

To increase the yield potential of *tropical* rice, it was necessary to improve the harvest index and nitrogen responsiveness by increasing the lodging resistance (Yoshida, 1981). Yoshida (1981) speculated that rice crop with fewer tillers would have a better canopy structure for light interception than the one with more tillers. The fewer tiller was an important characteristics for maintaining a high canopy photosynthetic rate when light was a limiting factor. Solar radiation had larger effect on tillering capacity and productive tillers percentage

Metzger *et al.* (1984) suggested that cultivars having semi-erect and somewhat wider leaves would produce higher yields with improved resistance to lodging. Lengthening the grain-filling period at the expense of the vegetative period did not increase grain yield .

Kim and Vergara (1991) proposed low tillering capacity of the plant for increasing grain yield potential and suggested the optimum number of tillers as five. Many ideotype traits such as plant height, tillers and panicle number, leaf orientation and grain weight will have selection targets in most cereal breeding programmes (Ramusson, 1991)

Cao *et al.* (1992) classified rice varieties into sink limiting, source limiting, intermediate types according to their source-sink relationship. Most *indica/japonica* rice lines belong to source limiting type, with a high ratio of spikelet number to leaf area at heading and low spikelet percentage.

Plant height was not necessarily the most important factor determining lodging resistance in rice. (Ookawa and Ishihara, 1992; Terashima *et al.,* 1992 and Easson *et al.,* 1993).

Cultivars with larger panicles produced fewer tillers than the cultivars with smaller panicles (Ise, 1992; Peng *et al.*, 1994 and Khush and Peng, 1997). Lu *et al.* (1994) reported that low filling spikelet percentage of *japonica / indica* hybrids mainly resulted from the number of sterile spikelets, which might be caused by poor compatibility between *japonica* and *indica* parents (Ikehashi and Wan, 1998).

Yuan (1997) attributed poor grain filling of *japonica / indica* lines to source limitation because of the large number of spikelets.

Japonica / indica hybrids possessed greater heterosis in biomass production than other rice hybrid combinations (Yuan, 1994 and Peng *et al.*, 1999). Four major barriers, however, had hindered the exploitation of the *japonica / indica* hybrids such as sterility, tall plant stature, long growth duration and poor grain filling (Yuan, 1998). So far, the first of three problems had been solved by the discovery and utilization of wide compatibility genes and other breeding strategies (Ikehashi,1984; Lu *et al.*,1994 and Yuan,1998).The last problem to solve was poor filling of fertilized grains (Yuan,1994,1998).Possible genetic, physiological and ecological causes of poor grain filling of *japonica / indica* hybrids had been recently investigated (Zhu *et al.*,1997;Wang *et al.*,1998 and Yang *et al.*,1999), but the cause of poor grain filling were unclear. There were two controversial hypotheses for the poor grain filling in *japonica / indica* hybrids.

Some investigators reported that limiting dry matter production caused by low photosynthetic rate and early senescence of leaves during grain filling period or relatively low ratio of source to sink resulted in poor gain filling of *japonica / indica* hybrids (Lu *et al.*, 1994 and Yuan, 1994). While Yang *et al.* (2002) found that *japonica / indica* hybrids had high dry matter accumulation during grain filling and their dry matter per spikelets was greater than that of inter varietal hybrids (Wang *et al.*,1998 and Yang *et al.*,1999), indicating the poor grain filling of *japonica / indica* hybrids was not a result of source limitation.

The yield of cultivars with small panicles depended heavily on panicle number, which was largely reduced under limited radiation such as in wet season .On the other hand, cultivars with extremely high number of tillers would have greater consumption of stored materials by excessively bigger sink size (Yoshida and Parao, 1976; Khush and Peng, 1997). Consequently, these stored materials, which were important under a low solar radiation condition (Laza *et al.*, 2003), would be reduced and less would be translocated to the grains. In addition, increase in tiller number caused over growth and mutual shading during the vegetative stage (Akita, 1998), which could be detrimental to Leaf Area Index (LAI) and crop growth rate. Excessive LAI could lead to increase in percentage of unfilled grain especially when solar radiation is low (Takeda, 1985 and Murata, 1995) as in the wet season.

In rice crop several factors influenced the response of leaf photosynthesis to light.First,elevated leaf temperatures that accompanied high irradiance had shown to cause metabolic imbalances (Pastenes and Horton,1996 a), deleterious effects on thylakoid function (Pastenes and Horton,1996 b),enhanced photo inhibition and enhanced photorespiration. Secondly, leaf angle had been identified as influencing the degree of light saturation of upper leaves (Yoshida, 1981b).Leaf orientation influenced the amount of light absorbed by altering both the level of reflectance and the available cross sectional area (He *et al.*, 1996 and Valladares and Pearcy, 1997).

Improving rice yield potential has been the main breeding objective in many countries for many years. Tongil was developed in Korea in 1971 from a *japonica / indica* cross (Chung and Heu, 1980).The variety showed a 30 percent yield increase compared with *japonica* varieties. Morphologically, Tongil was characterized by medium- long and erect leaves, thick leaf sheaths and culm, short plant height but long panicle, open plant type and lodging resistance. In 1982, in Japan super high-yielding rice-breeding program was initiated (Kushibuchi, 1997).

Peng *et al.* (2000) suggested that when radiation was limited as in wet season, it was difficult to improve grain yield by increasing panicle number because solar radiation had large effect on tillering capacity and ear bearing tiller percentage.

Translocation of assimilates and remobilization of stored assimilates from the straw to the grains during the grain filling period in *japonica / indica* hybrids was about 64 per cent which was significantly less than that of intervarietal hybrids. At maturity, only 44.1 per cent of ^{14}C fed to the flag leaves of *japonica / indica* hybrids was partitioned into grains and the rest remained in stems and leaves. Poor translocation and partitioning of assimilates to the grain of *japonica / indica* hybrids resulted in low harvest index. The results suggested that poor transport of assimilates to grains accounted for poor grain filling of *japonica / indica* hybrids (Yang *et al.*, 2002).

One of the major benefits of ideotype breeding is that breeder's are forced to define their goals and strategies in advance (IRRI, 1989). For example, based upon the morphological design postulated by Donald (1968), it was concluded that a successful crop plant needed high competitive ability relative to its mass and high efficiency relative to its use of environmental resources. It had showed that high-yielding cultivars of barley and rice were suppressed or eliminated in mixtures (Thurling, 1991). Therefore, a breeder would have to envisage different ideotypes when breeding crops for monoculture as opposed to mixed cropping systems, since the two systems represent two different kinds of competition. Using the ideotype approach, breeders select for and not against specific phenotypes.

2.2.2 Breeding for NPT lines at IRRI

IR-8, the first short statured rice variety developed at IRRI had a combination of desirable traits such as profuse tillering, dark green and erect leaves for good canopy architecture and sturdy stems. Its yield potential was 8-9 t per ha (Chandler, 1969). However, early generation high yielding varieties produced large number of unproductive tillers and excessive leaf area, which caused mutual shading and reduced canopy photosynthesis and sink size, especially when they were grown under direct sowing conditions (Evans, 1972).

In the late 1960s and early 1970s, yield of 9 to 10 t per ha was often reported for IR-8 and other early IRRI cultivars under favorable environment conditions at IRRI field trails, Philippines (Chandler, 1969 and Yoshida and Parao, 1972).In the late 1980's, it was postulated that the stagnant yield potential of semi-dwarf *indica* inbred rice cultivars might be the result of the plant type common to all of these germplasm.

Most of these cultivars had high tillering capacity and small panicles. A large number of unproductive tillers, limited sink size, and lodging susceptibility were identified as the major constraints to increased yield potential in these cultivars (Vergara, 1988).

Simulation model predicted that a 25 per cent increase in yield potential was possible by modifications of the following traits of the existing plant type (Dingkuhn *et al.*, 1991)

- ⇒ Enhanced leaf growth combined with reduced tillering during early vegetative growth
- ⇒ Reduced leaf growth and greater foliar nitrogen concentration during late vegetative and reproductive growth
- ⇒ A steeper slope of the vertical nitrogen concentration gradient in the leaf canopy with a greater proportion of total leaf area N in the upper leaves
- ⇒ Increased carbohydrate storage capacity in stems
- ⇒ A greater reproductive sink capacity and an extended grain-filling period.

The 'IR' cultivars produced large number of unproductive tillers and had excessive leaf area, which might cause mutual shading and a reduction in canopy photosynthesis and sink size, especially when grown under direct-seeded conditions (Peng *et al.*, 1994).

Yield potential of irrigated rice cultivars had been stagnant at the levels of 10 t per ha in dry season since the release of IR-8 in the 60's (Flinn *et al.,* 1982; Akita, 1994 and Peng *et al.,* 1994). Efforts were made to develop New Plant Type lines at IRRI with the goal of breaking the yield barrier since late 1980's and early 1990's. Breeding efforts to raise the yield potential focused on increase in photosynthetic rates, in biomass production and in harvest index. It was accomplished by reducing the plant height through incorporation of a recessive gene *sd1* for short stature (IRRI, 1989 and Cassman, 1994).

Many examples exist for achieving yield increases through the use of ideotype breeding for improved canopy architecture. In 1989, IRRI conceptualized and developed new ideotypes for annual upland, rain fed lowland and direct seeded irrigated rice. Table. 3 shows the characteristics of ideotypic rice plants. Ideotypic plants are designed to produce fewer tillers than the improved cultivars commonly grown today, but almost every tiller bear panicles. The new rice ideotype, which has a vigorous root system to draw nutrients from the soil, would be appropriate for both direct seeding and transplanting (Khush, 1995).

Although several crop physiologists proposed the framework of the new rice ideotype (Vergara, 1988; Janoria, 1989 and Khush, 1990), each of these proposed ideotype had a number of features in common. These traits were low tillering capacity, absence of unproductive tillers, 200-250 grains per panicle, 90-100 cm plant height ,thick and sturdy stem, vigorous root system, 110-130 days growth duration , increased harvest index of 0.6 or over 0.6 and grain yield of 13 to 15 t per ha.

2.2.3 Parental lines for NPT

Breeding work on the new plant type popularly known as 'super rice breeding' was conceptualized as early as in 1988, (IRRI, 1989; Vergera, 1988; Janoria, 1989 and Khush, 1990).Breeding work began in 1989 and hybridization was undertaken in 1990 dry season. About 2000 entries from the IRRI germplasm bank were grown to identify parents for various traits (Khush, 1995). *Bulu* varieties or *javonica* germplasms (*Tropical japonicas*) for low tillering and large panicles were intercrossed with short statured parents and genotypes with proposed ideotype were selected (Peng *et al.*, 1994).

Around 2000 *bulu* varieties were assessed in the field during 1989 and donors for developing NPT-*TJ* (*tropical x japonica)* were identified and presented in Table 4 (Peng *et al.*, 1994).In addition, to *bulus* from Indonesia, many *tropical japonica* donors were identified in germplasm from Malaysia, Thailand, Mynamar, Laos, Vietnam and Philippines (Virk and Khush, 2003).

Table 3. Characteristics of ideotypic rice plants.

Target ideotype traits	Upland rice	Low land rice	Direct-seeded irrigated rice
⇒ **Plant height**	130 cm	130 cm	90 cm
⇒ **Stems**	Very sturdy stems	Very sturdy stems	Very sturdy stems
⇒ **Leaves**	Erect upper leaves, droopy lower leaves	Dark green, erect or moderately droopy leaves	Dark green, erect and thick leaves
⇒ **Number of panicles per**	5-8	6-10	3-4
⇒ **Number of grains per**	150-200	150-200	200-250
⇒ **Root system**	Deep and thick roots	Extensive root system	Vigrous root system
⇒ **Growth duration**	100 days growth cycle	120-150 days growth	100-130 days growth cycle
⇒ **Disease and insect**	Multiple disease and insect	Multiple disease and	Multiple disease and insect
⇒ **Grain yield (t per ha)**	3-4	1 5-7	13-15
⇒ **Harvest index**	0.6	0.6	0.6 or over 0.6
⇒ **Grain dormancy**	---	Strong grain dormancy	----
⇒ **Tolerent to**	----	Strong submergence	----

Source: Adapted from IRRI (1989)

Table 4. Donors for various traits for developing NPT

Breeding traits	Name of donors
Short stature	MD-2, Shen-Nung 89-366
Low tillering	Merim, Geak, Gend jach Gempol, Gendjah Wangleal
Large panicle	Daringan, Djawa, Serang, Ketan Gubat
Thick stems	Sipapak, Sirah Bareh
Grain quality	WRC-4, Turpan-4, Jhumpaddy
Resistance to	**Name of Donors**
Bacterial blight	Ketan Lumbu, Tulak Bala
Blast	Moroberekan, Pring, Ketan Aram, Mauni
Tungro	Gundil Kuning, Jimburg, Lembang
Green Leaf Hopper	Pulut Cenrana, Pulut Senteus, Tua Dikin

2.2.4 China's super rice breeding

2.2.4.1 History and goals of super rice breeding

Since the development of first improved dwarf variety in Guangdong, China in 1959 (Huang, 2001) and a three-line *indica* hybrid in 1976 (Yuan *et al.*, 1994), breeding for high yielding varieties had never stopped in China. Huang (2001) developed bushy type rice varieties with early vigour such as Guichao and Teqing in the 1980s.These varieties were tolerant to shading and to high plant density and were widely grown in South China.

Zhou *et al.* (1995) developed a three-line intersub-specific F_1 hybrid between *indica* and *japonica* with heavy panicle type, ideal for rice growing areas such as Sichuan with high humidity, high temperature and limited solar radiation. Although progress had been achieved in increasing rice grain yield through crop improvement, China's rice breeding activities for increasing yield potential using ideotype approach was not organized at the national level until 1996. Yang *et al.* (1996) stated that further increase in rice yield potential had to come from the combination of improvement in plant type and utilization of growth vigour.They proposed the erect plant type and developed Shennong- 265 with this trait, which was grown in Liaoning province.The strategy for super rice breeding was to combine the ideotype approach with the use of inter sub-specific heterosis (Yuan, 1997).

Stimulated by IRRI's NPT breeding program, China established a Nation wide mega project on development of 'super rice' in 1996 (Cheng *et al.,* 1998).The project had the following objectives:

- To develop 'super rice' varieties with maximum yield of 13.5 t per ha by 2015 and 15 t per ha by 2025.
- To raise the national average rice yield to 6.9 t per ha by 2010 and to 7.5 t per ha by 2030 through the development of 'super rice' varieties.

The super rice breeding program was initiated in 1998 by Prof. Yuan Long Ping. In this program, the strategy was to combine an ideotype approach with utilization of intersubspecfic heterosis (Yuan, 2001).

The ideotype of super rice was reflected in the following morphological traits:

⇒ Moderate tillering capacity (270-300 panicles per m^2)

⇒ Heavy (5 g / panicle) and drooping panicles at maturity

⇒ Plant height of at least 100 cm (from soil surface to unbent plant tip) and panicle height of 60 cm (from soil surface to the top of panicles with panicles in natural position) at maturity

⇒ Top three leaves:

  - Flag leaf length of 50 cm and 55 cm for the 2 nd and 3 rd leaves. All three leaves above panicle height.
  - Should remain erect until maturity. Leaf angles of the flag, 2 nd and 3rd leaves are around 5^0, 10^0 and 20^0 respectively.

➢ Narrow and V-shaped leaves (2 cm leaf width when flattened)

⇒ Thick leaves (specific leaf weight of top three leaves=55g / m^2)

⇒ Leaf area index of top three leaves should be about 6.0

⇒ Harvest index of about 0.55

The success of super rice breeding in China was partially the result of assembling the good component of IRRI's design. This improvement in plant type was achieved by placing more emphasis on the properties of the top three leaves and the panicle position within the canopy. Both design focused on large panicle size, but source and sink relation were well balanced by improving photosynthesis and delaying leaf senescence of the top three leaves during the ripening stage. These morpho-physiological traits related to the top three leaves would be incorporated into second-generation NPT lines from IRRI in order to provide sufficient assimilates for grain filling of large panicles with 150 spikelets per panicles. Further, studies on NPT improvement were suggested, with the following objectives;.

(1) Understanding the physiological function of the morphological traits of NPT

(2) Identifying the factors that limit the grain filling of large panicles

(3) Studying the physiological basis of G x E interaction in yield potential

(4) Designing different NPT's for various environments

(5) Developing crop management strategies for achieving full expression of yield potential in NPT lines.

Success of super rice breeding in China and progress of NPT breeding in IRRI suggested that an ideotype approach was effective for breaking the yield ceiling of the irrigated rice crop. Peng *et al.* (2004) suggested that the following points should be recommended when ideotype breeding is used in various crops;

⇒ Genetic background of inferior donor parents for desirable traits may have a negative effect on performance of progenies (Marshall, 1991).It is necessary to select donor parents without severe defects in agronomic fitness.

⇒ The targeted morphological traits should be related to the physiological processes that determine the ultimate performance of the plant.

⇒ Extremes in plant type traits should be avoided (Belford and Sedgley, 1991).For example, the initial design of IRRI's NPT aimed at 200 to 250 grains per panicle, which resulted in poor grain filling. It is to be modified to 150 spikelets per panicle.

⇒ Interrelationship among the traits and compensation among the plant parts should be considered (Marshall, 1991). For example, there is a negative relationship between panicle size and panicle number per m^2. Only increase in overall biomass production can break this negative relationship and result in an improvement in yield potential (Ying *et al.,* 1998).

⇒ A new rice ideotype breeding may require concurrent modification of crop management such as seedling age, planting geometry, fertilization and weed control in order to fully express its yield potential (Abuelgasim, 1991).

2.2.5 Evaluation and performance of NPT lines

At IRRI, Philippines 1,10,000 pedigree lines were produced and more than 500 NPT lines were taken for evaluating in observation trails in 1993.The first generation NPT lines based on *tropical japonicas* were developed within less than 5 years (Peng *et al.*, 1994 and Khush, 1995).The first generation NPT lines were grown in a replicated observation trail at IRRI for the first time in 1993 during wet season and the characteristics of the NPT were compared with *indica* check varieties (Peng *et al.,* 1994). The morphological traits of NPT lines and their yield potential were better than *indica* varieties (Khush, 1995 and Khush, G.S. 1996).

In India, Janoria (1994) evaluated novel rice lines based on new ideotype and found high yield potential of the prototype lines as a result of very heavy panicle, reduced number of tillers and less leafy canopy.

Akita *et al.* (1996) conducted a field experiment at Japan during 1994 for evaluating two NPT lines developed by IRRI. NPT lines had fewer tillers but larger panicles. The yield of the NPT lines was lower than *indica* varieties, due to lower increase in dry weight after heading. Panicle number of the NPT lines was low, IR 65598-112-2 having the lowest (118-144).Spikelet number per panicle however was highest (326-367) in IR 65598-112-2.No lodging was observed in NPT lines, while cultivars lodged at mid-ripening phase.

Experiments by Yamagishi *et al.* (1996) at Japan revealed that NPT lines had reduced biomass production and poor grain filling rate than *indica* varieties and suggested that it was due to lack of apical dominance within a panicle. Other reasons for lower grain filling may be due to lack of compact arrangement of spikelets on the panicle (Khush,G.S. 1996), limited number of large vascular bundles for assimilates transport and source limitation due to early leaf senescence (Ladha *et al.*, 1998).

Yang *et al.* (1996) suggested that further increase in rice yield potential has to come from the combination of improvement in plant type and utilization of growth vigor. They proposed erect panicle plant type lines such as Shennong-265 grown in Liaoning Province in China.

Kumar *et al.(*1999) evaluated a set of 16 new plant type lines in India along with three stable check varieties viz.,MW-10,IR-36 and Kranti and reported that grain yield of NPT lines were either significantly superior or at par with the corresponding check varieties. NPT 63 K-12-51 had recorded highest grain yield of 9.17 and 9.94 (t per ha) for the *kharif and rabi* seasons.

Sanchez *et al.* (2000) found that IR 65598-112 and the two sister lines (IR 65600-42 and IR 65600-96) are promising NPT rice lines with high yield potential. But, these lines are susceptible to bacterial blight caused by *Xanthomonas oryzae Pv, oryzae.*

Lin *et al.* (2002) compared leaf area development of super rice Xieyou-9308 and *indica* Shanyou-63(used as a check) and found that grain yield of Xieyou-9308 reached 12.23 t per ha with crop growth duration of 150 days, panicle length of 26-28 cm, grain filling of 90 per cent and 1000-grain weight of 28 g.

Min *et al.* (2002) reported that China National Research Institute (CNRI) had developed super rice varieties such as Xieyou-9308 and Lianyoupeijiu which were commercially grown in farmer's field in large areas because they produced high yield with good grain quality.

Several promising super high-yielding cultivars such as Akenohoshi and Akichikara were developed at many breeding stations in Japan. They had high panicle weight with more number of fertile spikelets per panicle, large grain weight (Wang *et al.* 2002 a).

Zhu *et al.* (2002) attributed the high yield of super rice Xieyou - 9308 to large panicle size and greater spikelets number. In another study a yield of 11.7 t per ha was produced by Xieyou-9308, which was 20 per cent higher than the yield of check variety viz., Xieyou-63 (Wang *et al.*, 2002 b).

Peng and Khush (2003) reported that the second generation NPT lines at IRRI did not perform well in 2003 as in 2002 and suggested that it could be due to the fact that all second generation NPT lines had a lower spikelet number of 115 spikelets per panicle.

Peng *et al.* (2004) found that NPT lines significantly out yielded the check variety IR-72 with a yield of 10 t per ha in 2002 wet season. However, NPT lines IR 72158-16-3-3-1 and IR 72967-12-2-3 might not have expressed their yield potential fully since their harvest index was below 0.50 and grain filling was not greater than 80 percent. In the 2003 dry season the NPT line, IR 72967-12-2-3 was the top yielder. It produced 10.16 t per ha, which was significantly higher than IR -72 the *indica* check variety.

Peng *et al.* (2004) reported that China, from its super rice breeding programme, developed several F_1 hybrid varieties using the combination of intersub-specific crosses.

These hybrids produced a grain yield of 12 t per ha in on- farm demonstration trails, which was 8-15 per cent higher than hybrid *indica* check varieties.

Peng *et al.* (2004) reported that the first generation NPT lines had large panicles, few unproductive tillers and lodging resistance, but yield was disappointing because of low biomass and poor grain filling. Crop growth rate during the vegetative stage of NPT lines was lower than the *indica* varieties. Low biomass production was also associated with poor grain filling. The first generation NPT lines were susceptible to diseases and insects and had poor grain filling. Hence they could not be released for commercial cultivation. But were used as genetic materials in rice breeding programme worldwide.

Rebecca *et al.* (2004) observed that relative performance of the NPT lines with 150-200 spikelets per panicle was better in wet season than in dry season.However, large panicle was not always associated with high yield in wet season. Large panicle often resulted in reduced panicle number and poor grain filling percentage. Cultivars with larger panicles also had greater plant height (Visperas *et al.*, 2000), and longer growth duration (Akita,1988), which were undesirable traits in relation to lodging resistance.

Virk *et al.* (2004) reported that China had released three NPT lines viz., Dianchao-1 Dianchao-2 and Dianchao-3, developed from IR 64446-7-10-5 and IR-69097-AC2-1, two IRRI NPT (*tropical javanica)* lines. The NPT lines had performed very well in temperate areas, where disease pressure was low and consumers prefer sticky and bold grain types.

NPT lines introduced from IRRI and evaluated for agronomic traits in yield trails by both transplanting and direct-seeding in Korea by Moon and Kang (2006) , revealed that many breeding lines of NPT's were having undesirable characteristics such as late heading, poor grain filling, non-preferable grain quality, susceptibility to insect and disease and fast leaf senescence at maturity in Korean climatic condition and breeding efforts were made to develop the new NPT rice adaptable to Korean climatic condition.

Pandey (2006) reported that some *tropical japonica* rice-breeding lines based on new plant type concept, released in China and Indonesia received little attention in subtropics due to higher level of sterility, poor grain quality and longer duration. Efforts are underway to improve the NPT lines and to broaden to Korean climatic condition.

2.2.6 Breeding for second-generation NPT

IRRI's breeding of first- generation NPT lines using *tropical japonicas* did not produce high yield due to limited biomass production and poor grain filling. In 1995, progress had been made in the second-generation NPT lines, by crossing first-generation *tropical- japonica* NPT lines with elite *indica* parents and by modifying the original plant type design. Multiple site-year comparisons of first-generation NPT lines with the highest yielding *indica* varieties have shown that the original NPT design did not have sufficient tillering capacity.

Introduction of *indica* genes to *tropical-japonica* background to develop intermediate type varieties between *indica* and *japonica* had resulted in promising second-generation NPT lines. Breeding goals were to increase tillering capacity to improve biomass production and to compensate when tillers were lost due to insect damage or other causes during the vegetative stage. A slightly smaller panicle size without change in panicle length also appeared to be advantageous to reduce the compact arrangement of spikelets.Genes from *indica* parents had effectively reduced panicle size and increased tillering capacity in the second-generation NPT lines. *Indica* germplasm also helped to improve other NPT attributes such as grain quality and disease and insect resistance.Some second-generation NPT lines with the above refinement were, then selected and were planted in replicated observation trails for the first time in the 1998 wet season. These second- generation NPT lines had been tested in replicated yield trails since 2001 dry season and in the replicated agronomic trails in the 2002 dry season (Peng *et al.*, 2004).

2.2.7 Breeding of transgenic NPT lines for stem borer resistance

NPT lines developed with the target to increase the yield potential of rice by 20-25 per cent (Khush, 1995), at International Rice Research Institute, differed in genetic background and plant architecture from the semi dwarf *indica* varieties that predominated in *tropical* lowland areas. The NPT was derived from *tropical japonica* germplasm and had fewer and larger stems and panicles than semi- dwarf *indica* varieties. However, the yield potential of the NPT rice was limited by poor grain filling and susceptibility to insect pest and diseases (Khush, 1995). Genetic engineering could be used to complement the plant breeding efforts, which aimed to stabilize yield and increasing economic value by incorporating disease and insect pest resistance to NPT rice. The introduction of selectable marker gene into NPT lines though genetic engineering was reported by Alam *et al.* (1996).

Stem borer caused serious damage in NPT rice. *Bacillus thuringiensis*, the common soil bacterium produces crystals containing specific insecticidal proteins, which kill lepidopteran insects by binding and creating pores in the midgut membranes. Alam *et al.* (1998); Datta *et al.* (1998) and Tu *et al.* (1998) reported the transgenic rice with *Bt* gene conferring resistance to stem borer. The use of transgenic NPT rice plants expressing *Bt* proteins could be effective approach for controlling lepidopteron insect infestation on NPT rice.Experiments by Datta *et al.*(2003) reported the introduction of *Bt* gene [*cryIA (b)*], conferring the resistance to stem borer, directly into NPT rice line to achieve a high level of stem borer resistance.

A truncated chimeric *cryIA (b)* gene driven by the constitutive 35S promoter from CaMV, two tissue specific promoters, pith tissue and PEP-carboxylase (PEPC) gene for green tissue from maize were successfully introduced into the NPT (IR65600-42-5-2) line. A total of around 800 putative transgenic *Bt* rice plants were produced by microprojectile bombardment. Nine to twelve days old immature embryos were used as initial explant. Datta *et al.* (2003) observed different integration pattern of *Bt* gene with variable copy number shown in Southern analysis. More than 20 independently transformed plants were confirmed for integration of the *cryIA (b)* gene. About 190 plants showed the exact size banding pattern (1.8 kb). The putative transgenic plants appeared to be healthy in the CL4 transgenic greenhouse. However, due to grain filling problems only 20 per cent of the plants turned out to be fertile and normal.

2.2.8 Performance of second-generation NPT lines

In 1995, development of second-generation NPT lines was initiated by crossing first generation *tropical japonica* NPT lines with elite *indica* parents and replicated observation trials were conducted during wet season of 1998.But, replicated agronomic trails on the second generation NPT lines were started in the 2002 dry season and continued for four seasons.

According to Peng *et al.* (2004), experiments on second-generation NPT lines were conducted under flooded conditions at IRRI farm in dry season and wet season of 2002 and 2003. In 2002, eight-second generation NPT lines and one first- generation NPT line (IR-68552-100-1-2-2) were grown in comparison with an *indica* variety, IR-72.In 2003, five-second generation NPT lines and five *indica* check varieties were grown.

Five out of eight second generation NPT lines significantly out yielded the first generation NPT line.NPT lines IR-71700-247-1-1-2, IR-72158-16-3-3-1, IR-72967-12-2-3, IR-72158-16-3-3 recorded an yield potential of 9.75, 9.69, 9.59 and 9.35 t per ha respectively. Whereas the first-generation NPT line IR-68552-100-1-2-2 recorded about 6.34 t per ha.

In the 2002 dry season, four second-generation NPT lines produced significantly higher yield than the check variety (IR-72).The increase was due to improved biomass production in three NPT lines and due to improved harvest index in one NPT line. These four second generation NPT lines had larger panicles than IR-72.Spikelets per panicle of these NPT line was 45 to 75 per cent greater than that of IR-72.Among these four second generation NPT lines, NPT line IR 71700-247-1-1-2 produced higher yield , had same duration as IR-72 ,while other three were eight days later than IR-72.

In the 2002 wet season, two-second second-generation NPT lines produced significantly higher yield than the check variety (IR-72). IR-71700-247-1-1-2 was the top yielder in both dry and wet seasons, because its harvest index was the highest.IR-72164-348-6-2-2-2 had high yield in wet season, due to higher harvest index than IR-72.All the NPT lines had greater spikelet number per panicle than IR-72.The first-generation NPT line produced the lowest yield among all entries. The poor grain yield of the first-generation NPT line was again attributed low harvest index, which was the result of small sink size and low grain filling percentage. In general, all second generation NPT lines had longer growth duration than IR-72.

It is obvious that the yields of second generation NPT lines were higher than those of the first-generation NPT line. The yield increase was attributed to increased panicle number per m^2 (IR-71700-247-1-1-2 had highest panicles of 470) and improved grain filling percentage through the introduction of genes from elite *indica* parents to the first generation NPT lines. Several second-generation NPT lines exhibited greater yield than IR-72.IR-71700-247-1-1-2 had high harvest index in both dry and wet seasons.IR-72164-348-16-3-3-1 produced panicles with large number of spikelets. The yield improvement of second generation NPT lines over the *indica* checks could not be attributed to a common factor. Some second generation NPT lines produced more biomass and others had higher harvest index than *indica* check varieties. In general second -generation NPT lines had more spikelets per panicle than *indica* check variety, especially in 2002 .Most second generation NPT lines had durations not greater than 125 days (Peng *et al.*, 2004).

Stability parameters of second-generation NPT lines in rice, from IRRI were evaluated in CRRI, Orissa during wet and dry season of 2005.Grain yield of these lines out-yielded the first generation NPT lines and the best check varieties viz., IR-72 and PR-106 by overcoming biomass limitation and poor grain filling. Three NPT lines viz., IR 73963-120-CR-5-3-2, IR 72164-348-CR-6-2-2-3 and IR 71700-247-CR-1-1-1-1 recorded yields of 6.89,6.61 and 6.20 t per ha during wet season and 9.14,8.99 and 8.89 t per ha during dry season repectively.Compared to these ,the wet season yields of IR -72 and PR-106 were 4.8 and 5.1 t per ha respectively, while their respective yields of dry season were 6.1 and 6.6 t per ha .The higher yield of these NPT lines over the checks were clearly due to the improved total biomass and harvest index (Singh *et al.*,2006).

2.3 Genetic variability

The variability available in the breeding material is important in the selection of superior plant types. The genetic variation of quantitative character is influenced by environmental effects. The partitioning of the overall variance as genetic and non-genetic components becomes necessary for any effective breeding programme. The phenotypic and genotypic coefficients of variation above 20 per cent were taken as high, 10-19 per cent as moderate and below 10 per cent as low (Sivasubramanian and Madhavamenon, 1973).

In rice, Jangale *et al.* (1985) and Amirthadevarathinam (1990) observed high variability for plant height. While moderate variability was reported by Manomani (1991). Baskar *et al.* (1991) and Satpute (1992) observed genetic variation for days to 50% flowering, plant height and number of grains per panicle.

The highest coefficient of variation was observed for 1000-grain weight, length-breadth ratio and cooking traits. The highest variation was recorded for proportionate change (negatively), breadth-wise expansion, water absorption percentage and length-wise elongation (Sarawgi *et al.*, 1994).

Chaubey and Das (1998) reported that high GCV was observed in grain yield followed by grains per panicle. Similarly, High GCV and PCV were reported by Gonzales and Ramirez (1998) for grain yield per plant, panicle length and plant height.

Balan *et al.* (1999) recorded the highest GCV for grain yield followed by harvest index, whereas it was the lowest for days to maturity. Kaw *et al.* (1999) reported high genotypic variation for fertility percent, fertile spikelets, number per panicle and low for flowering duration and panicle length. The results were in agreement with Shivani and Reddy (2000).

Sadhukhan and Chattopadhyay (2000) reported that the grain yield had the highest PCV and GCV. Highest GCV value was recorded in number of grains per panicle.1000 grain weight, plant height, length and length / width ratio of grains and grain length after cooking had moderate to high GCV and PCV.

Mishra and Verma (2002) reported that kernel elongation ratio recorded the highest magnitude of GCV followed by biological yield per plant and grain yield per plant.

Yadav *et al.* (2002) evaluated 150 rice genotypes and reported that maximum variability was recorded for 1000-grain weight and amylose content. High estimates of genetic and phenotypic coefficients of variation were obtained for number of panicles, number of spikelets per panicle and grain yield per plant.

Khedikar *et al.* (2003) studied variability for different quantitative characters like plant height, tillers per plant, panicle length, test weight and grain yield per plant. They reported PCV was higher than GCV for all characters .The number of grains per panicle and panicle length showed a significant difference between PCV and GCV (Mahto *et al.*, 2003).

Genetic variability studies by Chand *et al.* (2004) revealed that GCV and PCV were high for grains per panicle and grain yield per plant.Raju *et al.* (2004) evaluated 21 genotypes and found that PCV and GCV were high for productive tillers per plant and 1000-grain weight. High values of GCV and PCV were recorded for grain yield per plant, biological yield per plant, number of tillers and panicles per plant by Vivek *et al.* (2004).

The values of PCV and GCV were high for panicle weight, spikelet number per panicle, test weight and grain yield per plant (Hasib, 2005). Sathyanarayana *et al.* (2005) evaluated 66 rice genotypes and reported high variability for number of grains per plant, spikelet fertility, days to 50 per cent flowering and plant height.

2.3 HERITABILITY AND GENETIC ADVANCE

The Heritability and Genetic Advance available in the breeding material is important in the selection of superior plant types. The genetic variations of quantitative characters are influenced by environmental effects. The partitioning of the overall variances as genetic and non-genetic components becomes necessary for any effective breeding programme. The phenotypic and genotypic co-efficient of variation above 20 per cent were taken as high, 10-19 per cent as moderate and below 10 per cent as low (Sivasubramanian and Madhavamenon, 1973).Heritability expresses the proportion of phenotypic variance to that of genotypic variance. The heritability estimate, which involves the breeding value of genotypes, serves as effective tool in predicting the performance.

In rice, high heritability combined with high genetic advance was observed by Chaudhury *et al.* (1980) and Paramasivan and Rangasamy (1988). Whereas Reddy *et al.* (1988) and Manomani (1991) observed high heritability with moderate genetic advance for plant height.

Reddy and Nerkar (1991) studied six yield related traits in the parental, F_1, F_2 and back cross generation from four high yielding *indica* rice crosses grown during *kharif,*1986 and reported that narrow sense heritability estimates were high for number of productive tillers per plant and 1000 grain weight and moderate for other characters, including grain yield.

Chauhan *et al.* (1992) reported high heritability estimates for kernel breadth and low value for water uptake. Genetic advance values were lowest for hulling and milling recovery.High variability was observed for yield and yield related characters viz., total number of spikelets, grain yield per plant, 1000-grain weight and lowest value was observed for panicle length (Chaubey and Singh, 1994).

Vivek *et al.* (2004) estimated the analysis of heritability and genetic advance in new plant type lines during the *kharif* season of 2002 at IRRI farm, Philippines along with 3 control cultivars, and compared 12 characters for yield and yield related characters. The results revealed a high variability coupled with high genetic advance for grain yield per plant, biological yield per plant, harvest index and number of grains per panicle.

Elayaraja *et al.* (2005) conducted an experiment to study the nature of genetic variability in rice from the popular rice variety PY-5. A high heritability coupled with a moderate to high genetic advance was reported for number of productive tillers, panicle length, number of grains per panicle, 1000-grain weight and grain yield per plant.

Twelve F_1 hybrids of scented rice and their seven parents were evaluated by Hasib (2005) for eight important panicle characters. The value of heritability and genetic advance were high for panicle weight, secondary branches per panicle, spikelet number per panicle, test weight and grain yield per panicle.

Sathyanarayana *et al.* (2005) reported that high heritability and genetic advance were recorded for number of grains per panicle, spikelet fertility, days to 50 percent flowering and plant height. Test weight recorded high heritability and genetic advance while number of productive tillers per plant and panicle length recorded low heritability.

Sinha *et al.* (2005) reported that estimates of heritability and GA were found high for plant height, tillers per plant, panicles per hill, panicle length, test weight and grain yield from 19 local rice varieties evaluated along with IR-36 as stable check variety.

Suresh and Anbuselvam (2005) reported that value of heritability and genetic advance were recorded highest for number of filled grains and grain yield per plant.

2.4 GENOTYPIC AND PHENOTYPIC CORRELATIONS

Correlations provide useful information to plant breeders for developing selection schemes as it reveal the strength of relationship among the group of characters. The extent of association between yield and its attributes can be known through correlations studies.

In rice, the number of large vascular bundles was correlated with the number of primary branches (Dana *et al.*, 1969; Matsushima, 1970; Hayashi, 1976 and Joarder and Eunus, 1980). Since, the high-density grains were located on the primary branches, panicles without secondary branches would be selected and panicles with large number of vascular bundles would be selected to increase primary branches and compensate for decrease in spikelet number with the removal of secondary branches. Grain filling rate and duration were positively correlated with grain size (Fujita *et al.*, 1984).

Positive correlation between days to flowering and grain yield was observed by Sampath (1984) and Rajeswari (1990). Kupkanchanakul and Roontum (1991) reported negative correlation between plant height and grain yield per plant.

Ise (1992) reported that harvest index exhibited negative and non-significant phenotypic correlation with productive tillers per plant.

Roy and Kar (1992) studied the phenotypic and genotypic correlations among 11 characters in 29 early maturing upland rice genotypes. Yield per plant and harvest index exhibited positive association with grain yield. Negative significant association of days to 50 per cent flowering and plant height with grain yield was observed.

Lio (2003) reported that in *indica* hybrid combinations, derived from B and R lines, the correlation between 1000-grain weight and chalky rice rate were positively significant.

Abhinav *et al.* (2004) studied correlation for yield components of 52 rice hybrids and revealed plant height, panicle length, number of ear bearing tillers per plant, total number of spikelets per panicle and 1000-grain weight were significantly and positively correlated with grain yield.

Kim *et al.* (2004) evaluated genetic divergence among *japonica* rice cultivars and assessed the relationship between genetic distance and hybrid performance in all possible non-reciprocal crosses among them. They reported that primary rachis branches per panicle was significantly correlated with grains on primary rachis branches per panicle, grain number per panicle and days to heading, but negative correlation with 1000- grain weight.

Field experiments were conducted at IRRI farm in 2000 wet season and 2001 dry season using 14 high yielding IR varieties and two F_1 hybrids under irrigated conditions and revealed that among all the measured yield-related traits, panicle size had the most consistent and closest positive correlation with grain yield (Rebecca *et al.*,2004).

Estimation of correlation, using 19 local rice cultivars along with IR-36 by Sinha *et al.* (2005) revealed significant positive genetic correlation for panicles per plant, 1000-grain weight and grain yield per ha.

Zhang *et al.* (2004) reported significant positive correlation between grain weight and chalkiness and suggested that it could be effective on the appearance of grain quality.

Zhou *et al.* (2004) reported that grain yield and cooking quality were not significantly correlated with 15 agronomic traits and nine-grain quality traits. Grain density was negatively and significantly correlated with chalkiness, amylose content and imperfect grain and positively with gel consistency and length-width ratio.

Babu *et al.* (2005) observed that days to 50 per cent flowering and 1000- grain weight were significantly and positively correlated with grain yield and harvest index.

Narpinder *et al.* (2005) evaluated 23 rice varieties for physiochemical, cooking and textural properties. The relationship between different properties was determined by using Pearson correlation and reported that cooking time showed a negative correlation with amylose content and a positive correlation with bulk density of milled rice.

2.5 Path coefficient analysis

Yield is a complex character and is influenced by number of traits, which are interrelated. The interdependence of these characters influences the direct relationship with yield and as a result, the information obtained on the association of these traits becomes unreliable. However, both coefficient analysis demonstrated by Dewey and Lu (1959) was used in partitioning the correlation coefficient into direct and indirect efforts. A path coefficient is a standardized partial regression coefficient and as such measures the direct influence of one variable upon another and permits the separation of correlation coefficient into components of direct and indirect effects.

Lu *et al.* (1988) reported that direct effect of yield related characters on grain yield was positive except for filled grains per panicle. Chaubey and Singh (1994) reported that number of ear bearing tillers exerted maximum direct effect on grain yield per plant followed by plant height and 1000-grain weight. Roy *et al.* (1995) concluded that grains per panicle and spikelets per panicle were the most important characters contributing to grain yield from the study of causal relationship in rice.

Mishra and Verma (2002) studied path analysis and indicated that flag leaf width had the greatest positive direct effect on grain yield, followed by flag leaf sheath, panicle length, harvest index, biological yield, and plant height. Flag leaf area showed the greatest positive direct effect on harvest index, followed by number of spikelets per panicle, number of ear bearing tillers per plant, 1000-grain weight, in a study of yield and its component using 16 cultivars grown at Raipur, India during *kharif* season of 1997-98.

Allahgholipour and Salehi (2003) estimated path analysis and reported that grain yield had positive and significant simple correlation with days to 50 per cent flowering, number of panicles per plant, number of tillers per plant and 1000 grain weight.

Surek and Besar (2003) derived eight breeding lines from 11 different cross populations in the F_2 generation in Turkey in 1995. Path coefficient analysis revealed that biological yield and harvest index had the positive direct effects on grain yield. Grain yield was significantly correlated with the component characters like the number of productive tillers per square meter, biological yield, harvest index and number of filled grains per panicle.

Raju *et al.* (2004) studied path analysis and reported that positive direct effect on grain yield was exhibited by plant height, 1000-grain weight and filled grains per panicle.

Sathyanarayana *al.* (2005) reported that yield was positively associated with spikelet fertility, panicle length, number of grains per panicle and number of effective tillers per plant. Panicle length and spikelet fertility exerted maximum direct effect on grain yield. High indirect effects of the different yield component traits studied were also noticed through spikelet fertility on grain yield.

Vaithiyalingan and Nadarajan (2005) conducted a field experiment to assess the nature and magnitude of association between grain yield and its components of rice hybrids. The path analysis disclosed that the number of grains per panicle had the highest positive direct effect on yield followed by productive tillers per plant, and suggested that direct selection for the above-mentioned traits could be effective for grain yield of rice hybrids.

Wan *et al.* (2005) compared the plant type traits between new and old varieties in *japonica* rice and path analysis revealed that the direct effect of grains per panicle and panicle number on yield were significant in old cultivars, while the direct effects of harvest index and panicle number were significant in new cultivars. The indirect effect of spikelet density on yield was significant in both new and old cultivars.

2.6 Genotype x Environment (G x E) Interactions

The present superior-yielding varieties exhibit variable performance because of a high proportion of G x E interaction. There is a need to identify and release stable yielding varieties even on a specific-areas basis, instead of relatively less stable varieties on a wide area basis. There are strong genotypic differences among varieties for this interaction as well as methods for selecting varieties that are stable across environments. Prior to releasing varieties, it is possible to select varieties with a stable performance even in unfavorable environments or management regimes.

Several workers considered G X E interaction as linear functions of environment and proposed regression of yield of a genotype on the mean yield of all genotypes in each environment to evaluate genotype performance stability (Eberhart and Russell, 1966 and Perkins and Jinks, 1968).

Twenty tall *indica* rice genotypes evaluated under 3 sowing dates had significant differences due to genotypes, environments and genotype x environment interactions for days to 50 per cent flowering, plant height, grain weight and grain yield. The genotype IET-7970 showed general adaptability for grain yield and earliness with a high level of performance and suitability for rainfed lowland conditions (Singh, 1995).

Estimates of stability analysis was done by Bhave *et al.* (2004) in 17 CMS lines of rice over different environmental conditions during *kharif* season of 2001. Pooled analysis of variance revealed the existence of significant genetic differences among the CMS lines for all the characters. The mean square due to G x E (linear) were significant for all the traits, indicating the presence of linear component of G x E interaction.

An experiment was conducted to evaluate 69 advanced breeding lines from IRRI, Philippines, including 5 Korean rice cultivars using a cold-water irrigation facility to identify promising cold tolerant genotypes The IRRI lines consisted of 51 NPT's and 18 bred for high altitude area. It was revealed that of these 69 IRRI breeding lines, two NPT lines viz., IR 61727-4B-1-1-1 and IR 66160-121-4-4-2 were identified as the most promising genotypes for cold tolerance (Jena *et al.*, 2004).

Chuangen and Shi (2006) identified two released inter subspecies hybrids as the pioneers of super hybrid rice viz., Liangyoupeijiu {Peiai 64 S / 9311(*javanica/ indica*)} and Liangyou E-32 {Peiai 64 S / E 32 (*javanica / japonica*)}, both of which exhibited grain yield higher than 10.5 t per ha.Out of them, Liangyoupeijiu had been successfully popularized over 5 m.ha in wide climatic areas, while Liangyou E- 32 made a yield record and offered a model plant ideotype for super hybrid rice.

Moon and Kang (2006) evaluated four super rice cultivars at temperate regions of Korea and gave a yield of 6.8-7.4 t per ha of milled rice. These genotypes featured the superiority in plant architecture, photosynthetic efficiency, nitrogen response and root vigorousness resulting in adjusting the rice plant type to maximized yield in Korean climatic condition. Yield potential of NPT rice cultivars increased to above 40-43 per cent in both *japonica* and Tongil type rice as compared with those of earlier developed *japonica* and Tongil varieties.

2.7 GRAIN QUALITY

Bhattacharya and Soubhagya (1972) found that slender grain varieties cooked faster than bold grained varieties. Fine-grained varieties had higher elongation ratio than the coarse-grained varieties (Dhaliwal *et al.*, 1989).

Ali *et al.* (1993) reported that high head rice recovery and total milled rice were obtained from harvesting at 20-23 per cent grain moisture content. Delaying harvesting to lower moisture content decreased head rice recovery but had little effect on milled rice and cooking quality.

In rice, cultivars were studied for test weight and length-breadth of polished kernels. Correlation indicated that weight of grain was influenced more by length than that of L/B ratio of kernels (De *et al.*, 1994).Ten aromatic rice germplasms were evaluated for determining their physio-chemical characteristics. The results indicated that eastern *indica* scented varieties were mostly having medium slender grains with high head rice recovery, around 20 per cent amylose content and excellent elongation ratio (Malik *et al.*, 1994).

Sadha *et al.* (1996) studied cooking qualities of six rice cultivars of Himachal Pradesh. Significant variation in different cooking quality parameters was observed for water uptake ratio, kernel elongation ratio, cooking time, alkali-spreading value and volume expansion ratio. Himalaya - 2216 was identified as best in cooking quality.

Khush *et al.* (1998) studied grain quality of hybrids and their parents and concluded that the genetic heterozygosity of hybrids did not affect the grain quality as long as one of the parents was not of poor in grain quality.

Rani *et al.* (1998) reported that rice hybrids exhibited a high volume expansion ratio of 5.3 with most desirable amylose content (20-25 per cent).

Two hundred scented rice cultivars and one non-scented control were evaluated for milling and quality characteristics by Nayak *et al.* (2003).The scented genotype showed stable response for milling and hulling percentage, head rice recovery, water uptake, elongation rate and amylose content.

Patil *et al.* (2003) observed a wide range of variation for amylose content, alkali spreading value and kernel length-breadth ratio of cooked rice in aromatic rice and improved controls.

Zhang *et al.* (2004) studied the appearance and correlation of rice quality characters in hybrids and found that head rice recovery was significantly and positively correlated with chalkiness and chalk score and was significantly and negatively correlated with gel consistency.

Nayak and Reddy (2005) studied seasonal influence on quality characters in scented rice and reported that higher milling and hulling percentage were observed during *rabi* season, due to higher binding of glucose molecules and more sunshine hours during grain filling. The head rice recovery was also high during the *rabi* season due to the compactness of starch in the endosperm.

MATERIALS & METHODS

3. Materials & Methods

The study entitled on "Genotype - Environment interaction in New Plant Type (NPT) lines of rice (*Oryza sativa* L.,)"was carried in the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara during the *rabi* season of 2005.The field experiments were laid at three locations in farmers' field of Palghat district viz., Nenmeni, Thenkurissi and Mathur.The general climatic features of Palghat district is given in Appendix 1.

3.1 Materials

A set of eight selected NPT Lines from IRRI, Philippines along with Jyothi as a local check variety constituted the materials for study (Table. 5). Seeds of these lines were received from Central Rice Research Institute (CRRI), Cuttack, Orissa, India.

Table 5. Details of NPT lines used for the experiment

S.N	Genotypes	Accession Number	Parentage
1.	NPT-1	IR 73971-87-1-1-1-1	IR 68058-71-2-1 / IR 68552-55-3-2
2.	NPT-2	IR 71676-90-2-2	IR 65564-22-2-3 / PSBRC 2
3.	NPT-3	IR 73707-45-3-2-3	IR 69133-49-1-3 / IR 67962-84-2-2 / IR 67303-7-3-4-1
4.	NPT-4	IR 72176-140-1-2-2	IR 68312-20-4-2-1-1 / IR 66159-131-4-3-
5.	NPT-5	IR 73933-8-2-2-3	IR 65629-157-3-2-3-2-1 / IR 68763-46-1-
6.	NPT-6	IR 71703-857-1-3	IR 66738-118-1-2 / PSBRC 2
7.	NPT-7	IR 72158-116-6	BG90-2 / IR67962-84-2-2-2
8.	NPT-8	IR 72158-68-6-3	BG90-2 / IR 67962-84-2-2-2
9	Jyothi	-	PTB -10 X IR- 8

3.2 Methods

3.2.1 Experiment

A set of eight selected NPT lines of rice developed at IRRI, Philippines, along with Jyothi as check variety were compared in a yield trail. The experiments were conducted at three different agro climatic situations of Palghat district located in central zone of Kerala viz., Nenmeni, Thenkurissi and Mathur, during *rabi* season of 2005.

Field trails were laid out in a Randomized Block Design (RBD) with three replications at each environment, with a net plot size was $9m^2$ and a spacing of 15 x 10 cm. Standard cultural practices and plant protection were followed according to Package of Practices Recommendations: Crops (2002) by Kerala Agricultural University.

The data was recorded from 10 randomly selected plants in each plot and mean was worked out. Observations were taken based on the Standard Evaluation System of Rice (IRRI, 1995) and data was analysed according to standard statistical procedures.

3.2.2 Observations recorded

1) Days to 50 % flowering

Numbers of days were taken from date of germination to 50 percentage of flowering stage within a plot.

2) Days to maturity

Numbers of days from germination to grain ripening (when 85 percentage of panicles were matured) were recorded.

3) Height of plant (cm)

Height of plant was recorded at the time of harvest from soil surface to tip of the primary panicle in centimetres and observations were recorded from 10 hills per plot.

4) Number of total tillers per plant

Ten plants were randomly selected from each plot and the mean was worked out to record the total tillers for each plant.

5) Number of productive tillers per plant

Number of productive tillers in a plant was recorded prior to harvest. Observation was recorded from 10 plants per plot.

6) Number of spikelets per panicle

Number of filled spikelets from ten panicles was counted to record the spikelets per panicle and the mean was worked out.

7) Panicle length (cm)

Length of panicle was measured from the neck of the panicle to tip of the panicle and expressed in centimetres.

8) Grain yield (t per ha)

The plants from each plot were harvested excluding border rows and the grain yield was expressed in t per ha .

9) Straw yield (t per ha)

The plants from each plot were harvested excluding border rows and the straw yield was recorded in t per ha.

10) 1000-grain weight (g)

Weight of 1000 fully ripened grains taken at random from each entry and expressed in grams.

11) Harvest index

The proportion of economic yield reported over biological yield, using the formula (Donald and Hamblin, 1976).

$$\text{Harvest Index} = \frac{\text{Grain yield}}{\text{Biological yield (grain + straw yield)}}$$

12) L / B ratio

L / B ratio is estimated by dividing the grain length by grain width and expressed in mm (IRRI, 1995),

$$\text{L / B ratio} = \frac{\text{Grain length (mm)}}{\text{Grain width (mm)}}$$

L / B ratio was expressed as grain shape and classified as follows :

Grain shape	L / B ratio
Slender	Over 3.0
Medium	2.1 to 2.9
Bold	1.1 to 2.0
Round	Less than I

13) Milling percentage

One kg of parboiled paddy samples were milled for 30 seconds and milling percentage calculated as,

$$\text{Milling percentage (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of rough paddy}} \times 100$$

14) Head rice recovery (%)

Five grams of rice per milled sample was used to study head rice recovery and was calculated as,

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of total rice taken}} \times 100$$

15. Cooking qualities

Cooking qualities such as amylose content, alkali spreading value, volume expansion ratio and kernel elongation ratio were studied, using the following procedures.

(a) Amylose content

100 mg parboiled milled rice was powdered using pestle and morter. To this sample, one ml of distilled ethanol was added, 10 ml of 1 N Na OH was added to this sample and was kept overnight. Then the volume was made upto 100 ml. 2.5 ml of the extract was taken in a test tube and added 20.0 ml of distilled water and three drops of phenolphthalein. Then 0.1 N Hcl was added drop by drop until the pink colour just disappeared. To this 1.0 ml of iodine reagent was added and the volume made upto 50 ml.The colour developed was read at 590 nm using spectrometer. 0.2, 0.4, 0.6, 0.6, 0.8, and 1.0 ml of standard amylose solution was taken and developed colour as in sample. Using the standard graph, the amount of amylose present in the sample was calculated. One ml of iodine was taken and diluted to 50 ml for a blank (Sadasivam and Manickam, 1992).

Absorbance corresponds to 2.5 ml of the test solution = x mg amylose

$$100 \text{ ml extract} = \frac{X}{2.5 \text{ ml} \times 100 \text{ ml amylose}} \times 100 \text{ mg} = \% \text{ amylose}$$

Rice varieties were grouped on the basis of their amylose content into waxy (1-2 per cent amylose), low amylose (8-19 per cent), intermediate amylose (20-25 per cent) and high amylose (>25 per cent) (IRRI, 1972).

b) Alkali spreading value

Ten milled rice kernels were placed in 10.0 ml of 1.7 per cent of KOH in a petriplate. The kernels were so arranged that they did not touch each other. They were allowed to stand for 23 hours at 30 ^{0} C. The appearance and disintegration of the kernels were rated after incubation based on the following scale (IRRI, 1995) .

Code	Description	Alkali Digestion	Gelatinization Temperature
1.	Not affected but chalky	Low	High
2.	Swollen	Low	High
3.	Swollen with collar incomplete or narrow	Low or intermediate	High or intermediate
4.	Swollen with collar complete and wide	Intermediate	Intermediate
5.	Split or segmented with collar complete and wide	Intermediate	Intermediate
6.	Dispersed merging with collar	High	High
7.	Completely dispersed and cleared	High	High

c) Kernel elongation ratio

Kernel elongation ratio was determined as described by Azeez and Shafi (1966). Ten raw and ten cooked kernels were taken at random and their length was measured and ratio calculated as follows.

$$\text{Kernel elongation ratio} = \frac{\text{Mean length of cooked kernel}}{\text{Mean length of raw kernel}}$$

d) Volume expansion ratio

The volume of raw rice as well as cooked rice was determined by water displacement method using a measuring cylinder (Onate and Delmundo, 1966) and volume expansion ratio was calculated as

$$\text{Volume expansion ratio} = \frac{\text{Volume of cooked rice}}{\text{Volume of raw rice}}$$

3.3 STATISTICAL ANALYSIS

The data obtained from three locations viz., Nenmeni, Thenkurissi and Mathur, were subjected to location wise analysis of variance and stability analysis.

3.3.1 Estimation of genetic parameters

The variance components were estimated as suggested by Singh and Choudhary (1985).

3.3.1 (a) Phenotypic variance

$$\text{Phenotypic variance } (Vp) = Vg + Ve$$

Where (Vg) = Genotypic variance

(Ve) = Environmental variance

3.3.1 (b) Genotypic variance

$$\text{Genotypic variance } (Vg) = \frac{VT - VE}{N}$$

Where VT = Mean sum of squares due to treatments

VE = Mean sum of squares due to error

Environmental variance (Ve) = VE

Where V E = Mean sum of squares due to error

N = Number of replications

3.3.1(c) Phenotypic and genotypic coefficients of variation

The Phenotypic and genotypic coefficients of variation were calculated by the formula suggested by Burton and Devane (1953).

$$\text{Phenotypic coefficients of variation (PCV)} = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

where, Vp = Phenotypic variance

$\bar{X}$ = Mean of the character under study

$$\text{Genotypic coefficients of variation (GCV)} = \frac{\sqrt{Vg}}{\bar{X}} \times 100$$

where, $\sqrt{Vg}$ = Genotypic variance

$\bar{X}$ = Mean of the character under study

The estimates of PCV and GCV were classified as (Sivassubramanian and Madhavamenon, 1973)

High	=	> 20 percent
Moderate	=	10-20 percent
Low	=	< 10 percent

3.3.1(d) Heritability

Heritability in the broad sense was estimated by the following the formula suggested by (Reeve, 1955 and Robertson, 1959).

$$\text{Heritability } (H^2) = \frac{Vg}{Vp} \times 100$$

Where, Vg = Genotypic variance

Vp = Phenotypic variance

The heritability was categorised as (Robinson *et al.*, 1949)

High = 60-100 percent

Medium = 30-60 percent

Low = < 30 percent

3.3.1(e) Genetic advance

The expected genetic advance is measured by the formula suggested by Johnson *et al.* (1955) at five percent selection, using the constant K as 2.06 given by Allard (1960).

$$\text{Expected Genetic Advance (GA)} = \frac{Vg}{Vp} \times K \times \sqrt{Vp}$$

Where Vg = Genotypic variance

Vp = Phenotypic variance

K = Selection differential

3.3.3 (f) Genetic gain (Genetic advance as percentage of mean)

Genetic advance (GA) calculated in the above method was used for estimation of genetic gain.

$$\text{Genetic gain (GG)} = \frac{GA}{\overline{X}} \times 100$$

Where $\bar{X}$ =Mean of the character under study.

Genetic gain was categorised as (Robinson, 1949)

High = > 20 per cent

Medium = 10 - 20 per cent

Low = < 10 per cent

3.3.1(g)Phenotypic and genotypic correlation coefficients

Phenotypic and genotypic correlation coefficients were worked out in the same way as the variances were calculated. Mean product expectations of the covariance analyses are analogous to the mean square expectations of the covariance. The different covariance estimates were calculated by the method suggested by Fisher (1954), using the statistical package SPAR-1.

Phenotypic covariance between two characters

$$1 \text{ and } 2\ (CoVp1.2) = CoVg\ 1.2 + CoVe\ 1.2$$

Where,

CoVg 12 = Genotypic covariance between characters 1 and 2

CoVe 12 = Environmental covariance between characters 1 and 2

Genotypic covariance between two characters 1 and 2 is as follows

$$CoVg\ 12 = \frac{Mt\ 12 - Me\ 12}{N}$$

Where,

Mt 12 = Mean sum of product due to treatment between characters 1 and 2

Me 12 = Mean sum of product due to error between characters 1 and 2

N = Number of replications

The phenotypic and genotypic correlation coefficients among the various characters were worked out in all possible combinations according to the formula suggested by Johnson *et al.* (1955).

Phenotypic correlation coefficient between two characters 1 and 2.

$$(r_{p\,12}) = \frac{Co\,Vp\,(12)}{\sqrt{Vp\,1.\;Vp\;\;2}}$$

Where,

CoVp 1 2 = Phenotypic covariance between characters 1 and 2

Vp 1 = Phenotypic variance of character 1

Vp 2 = Phenotypic variance of character 2

Genotypic correlation coefficient between two characters 1 and 2.

$$(r_g\,12) = \frac{CoVg\,(1\;\;2)}{\sqrt{Vg1.\,Vg\,2}}$$

Where,

CoVg(1 2) = Genotypic covariance between characters 1 and 2

Vg 1 = Genotypic variance of character 1

Vg 2 = Genotypic variance of character 2

3.3.1(h) Path analysis

Path analysis was carried out by methods by Singh and Chaudhary (1985).

3.3.1(i) Stability analysis

Stability in performance is one of the most desirable properties of a genotype to be released as a variety for wide cultivation. The model of Ebehart and Russel (1966) was used for stability analysis. As per this model, a stable variety with high mean than grand mean, with unit regression coefficient (b=1) and the deviation not significantly different from zero ($S^2d=0$) is said to be stable. When a variety with regression coefficient above unity, it is said to be favourable environments. For carrying out various statistical analyses, the software package SPAR-1 was used.

RESULTS

4. Results

The analysis of Genotype – Environment (G x E) interaction in eight NPT lines along with Jyothi as check variety was carried out in a multi location trail at three different locations viz., Nenmeni, Thenkurissi and Mathur in Palghat district during *rabi* 2005.The results of these trials are presented in Tables 6-25.

4.1 Mean performance and variability

4.1.1 Mean performance

The mean performance of genotypes at each location was analysed for significant difference using Duncan's Multiple Range Test and the results are presented in Tables 6, 7 and 8.In general NPT lines recorded low mean values for number of days to 50 per cent flowering, 1000-grain weight and amylose content at all the three locations when compared to check variety (Jyothi). On the other hand plant height, panicle length and head rice recovery were high at all the three locations.

At Nenmeni (Table 6), in general NPT lines recorded low mean values for days to 50 per cent flowering ,days to maturity, number of total tillers per plant ,number of productive tillers per plant,1000-grain weight, L/B ratio, milling percentage, kernel elongation ratio, volume expansion ratio and amylose content. On the other hand, plant height, number of spikelets per panicle, panicle length, grain yield, straw yield and head rice recovery were high mean values.NPT lines and check variety (Jyothi) recorded same mean value for harvest index.

All the NPT lines and Jyothi had performed uniformly for number of days to 50 per cent flowering.NPT-4 and NPT-5 recorded significantly low mean values (106.43 and 107.21 days respectively) for number of days to maturity whereas Jyothi took significantly high number of days to maturity (118.10 days) than NPT lines. Significantly low plant height was recorded by Jyothi (85.20 cm).Number of total tillers

Table 6. Mean performance of NPT lines and check variety for different quantitative characters at Nenmeni, Palghat (*Rabi* , 2005)

S.N	Genotypes	Characters									
		Days to 50 % flowering (days)	Days to maturity (days)	Height of plant (cm)	Number of total tillers per plant	Number of productive tillers per plant	Number of spikelets per panicle	Panicle length (cm)	Grain yield (t per ha)	Straw yield (t per ha)	Harvest index
1	NPT-1	81.24 ^{a}	110.01 ^{b}	93.88 ^{bcd}	11.93 ^{ab}	10.67 ^{ab}	141.53 ^{abc}	23.83 ^{bc}	6.62 ^{a}	7.65 ^{a}	0.46 ^{ab}
2	NPT-2	82.37 ^{a}	111.14 ^{c}	92.03 ^{b}	12.97 ^{b}	11.07 ^{ab}	200.33^{d}	21.60 ^{a}	9.82 ^{b}	10.84 ^{c}	0.47 ^{ab}
3.	NPT-3	88.20 ^{a}	116.31 ^{c}	98.87 ^{d}	12.27 ^{ab}	11.33 ^{b}	172.23^{c}	25.53 ^{d}	9.66 ^{b}	10.65 ^{c}	0.47 ^{ab}
4	NPT-4	83.43 ^{a}	106.43 ^{a}	92.28 ^{b}	12.97 ^{b}	11.70 ^{b}	159.57 ^{bc}	21.18^{a}	9.12 ^{b}	10.41^{c}	0.48 ^{b}
5	NPT-5	82.15 ^{a}	107.21 ^{a}	98.32 ^{cd}	13.30 ^{b}	11.50 ^{b}	150.93 ^{abc}	24.72 ^{cd}	9.08 ^{b}	9.97 ^{b}	0.48 ^{b}
6	NPT-6	87.01 ^{a}	110.10 ^{b}	91.03 ^{b}	12.87 ^{ab}	11.70 ^{b}	150.93 ^{abc}	25.43 ^{d}	8.72 ^{b}	9.97 ^{b}	0.45 ^{a}
7	NPT-7	86 .21^{a}	116 .21^{c}	93.28 ^{bc}	12.43 ^{ab}	11.20 ^{b}	141.53 ^{abc}	25.14 ^{cd}	8.68 ^{b}	9.40 ^{b}	0.48 ^{b}
8	NPT-8	89.31 ^{a}	115.31 ^{c}	95.26 ^{bcd}	10.82 ^{a}	9.33 ^{ab}	134.40 ^{ab}	23.14 ^{b}	6.71 ^{a}	7.37 ^{a}	0.48 ^{b}
9	Jyothi	89..00 ^{a}	118.10 ^{d}	85.20 ^{a}	15.60 ^{c}	12.17 ^{b}	122.07 ^{a}	21.18 ^{a}	5.88 ^{a}	6.57 ^{a}	0.47 ^{ab}
	Mean of NPT lines	**84.95**	**111.59**	**94.37**	**12.44**	**11.06**	**157.58**	**23.82**	**8.55**	**9.53**	**0.47**

Cond...

Table 6. Mean performance of NPT lines and check variety for different quantitative characters at Nenmeni, Palghat (*Rabi,* 2005)

S.N	Genotypes	Characters							
		1000-grain weight (g)	L/B ratio	Grain Shape	Milling percentage	Head rice recovery (%)	Kernel elongation ratio	Volume Expansion ratio	Amylose Content (%)
1	NPT-1	25.00 ^{b}	3.60 ^{e}	Slender	75.83 ^{a}	77.07 ^{a}	1.65 ^{b}	5.36 ^{b}	17.39 ^{e}
2	NPT-2	25.50 ^{bc}	3.30 ^{c}	Slender	76.40 ^{a}	82.68 ^{bc}	1.66^{b}	5.13 ^{b}	10.78 ^{b}
3.	NPT-3	26.50 ^{c}	3.50 ^{de}	Slender	76.63 ^{a}	84.93 ^{cd}	1.52^{a}	5.64 ^{c}	9.55 ^{a}
4	NPT-4	25.73 ^{bc}	3.10 ^{b}	Slender	80.67 ^{c}	84.53 ^{cd}	1.47 ^{a}	5.23 ^{b}	17.21^{e}
5	NPT-5	25.73 ^{bc}	3.70 ^{e}	Slender	76.63 ^{a}	77.47 ^{a}	1.68 ^{b}	5.35 ^{b}	9.96 ^{ab}
6	NPT-6	22.10 ^{a}	3.40 ^{cd}	Slender	78.43 ^{bc}	90.00 ^{de}	1.53 ^{a}	4.90 ^{ab}	15.78 ^{d}
7	NPT-7	27.97 ^{de}	2.80 ^{a}	Medium	75.73 ^{a}	90.51^{e}	1.71 ^{b}	4.40 ^{ab}	12.36 ^{c}
8	NPT-8	29.10 ^{e}	2.83 ^{a}	Medium	76.98 ^{ab}	89.00^{de}	1.46 ^{a}	5.47 ^{b}	12.30 ^{c}
9	Jyothi	26.75 ^{cd}	3.87 ^{f}	Slender	79.33 ^{bc}	81.53 ^{a}	1.66^{b}	5.45 ^{b}	18.74 ^{f}
Mean of NPT lines		**25.96**	**3.28**		**77.16**	**84.52**	**1.61**	**5.20**	**13.16**

per plant was significantly high for Jyothi variety(15.60).With regard to number of productive tillers per plant,NPT-8 had recorded low mean value of 9.33.

The highest (significantly high) number of spikelets per panicle (200.33) was recorded by NPT-2. The lowest (significantly low) panicle length was recorded by NPT-4(21.18 cm), Jyothi (21.18 cm) and NPT-2(21.60cm).With regard to grain yield and straw yield , significantly low values of grain and straw yields were recorded by Jyothi, NPT-1and NPT-8.The corresponding grain yields were 5.88, 6.62 and 6.71 t per ha respectively and straw yields were 6.57, 7.65 and 7.37 t per ha respectively. 1000-grain weight was significantly low for NPT-6(22.10g).Significantly high L/B ratio was recorded by Jyothi (3.87) and significantly low was exhibited by NPT-7 and NPT-8 (2.80 and 2.80 respectively), which were produced medium sized grains. Head rice recovery was significantly low for the genotypes NPT-1(77.07), NPT-5(77.47 per cent) and Jyothi (81.53 per cent).Significantly high volume expansion ratio was recorded by NPT-3(5.64). Jyothi had significantly high mean value for amylose content (18.74 per cent).

At Thenkurissi (Table 7), in general NPT lines recorded low mean values for days to 50 per cent flowering, 1000-grain weight, L/B ratio and amylose content. On the other hand, days to maturity, plant height, number of total tillers per plant, number of productive tillers plant, number of spikelets per panicle,panicle length, grain yield, straw yield, milling percentage ,head rice recovery and volume expansion ratio were high mean values. .NPT lines and check variety (Jyothi) recorded same mean value for harvest index.

In general, NPT lines took lesser number of days to 50 per cent flowering. Low mean value was recorded by NPT-2(79 days) and it was on par with NPT-1(81 days) and NPT-4(82 days).Significantly high number of days for maturity was exhibited by NPT-7 (118.21 days).Number of productive tillers per plant was significantly high for NPT-8(15.73). The highest number of spikelets per panicle was recorded by NPT-5(152.63).Significantly low mean values of grain yield recorded by NPT-1 and Jyothi (5.11 and 5.18 t per ha respectively). Straw yields of these genotypes were 5.67 and 5.63 t per ha respectively.

Table7. Mean performances of NPT lines and check variety for different quantitative characters at Thenkurissi, Palghat (*Rabi* , 2005)

S. N	Genotypes	Characters									
		Days to 50 % flowering (days)	Days to maturity (days)	Height of plant (cm)	Number of total tillers per plant	Number of productive tillers per plant	Number of spikelets per panicle	Panicle length (cm)	Grain Yield (t per ha)	Straw yield (t per ha)	Harvest index
1	NPT-1	81.20 ^{ab}	114.00 ^{c}	91.35 ^{bc}	15.90 ^{a}	13.00 ^{a}	134.87 ^{ab}	22.90 ^{bc}	5.11 ^{a}	5.67 ^{a}	0.47 ^{a}
2	NPT-2	79 .31^{ab}	113.00 ^{b}	87.97 ^{ab}	15.90 ^{a}	14.40 ^{ab}	135.67 ^{ab}	21.52 ^{a}	7.80 ^{c}	8.37 ^{cd}	0.46 ^{a}
3.	NPT-3	89.15 ^{b}	115.42 ^{d}	92.52 ^{bc}	14.57 ^{a}	14.53 ^{ab}	135.90 ^{ab}	25.20 ^{f}	7.64 ^{b}	8.57 ^{d}	0.47 ^{a}
4	NPT-4	82 .23^{ab}	109.14 ^{a}	82.58 ^{a}	14.33 ^{a}	12.60 ^{a}	124.43 ^{a}	22.05 ^{ab}	6.72 b	7.24 ^{bc}	0.47 ^{a}
5	NPT-5	88.00 ^{b}	115.32 ^{d}	97.07 ^{c}	14.70 ^{a}	13.10 ^{a}	152.63 ^{c}	24.52 ^{ef}	8.25 ^{c}	8.12 ^{cd}	0.49 ^{a}
6	NPT-6	89.67 ^{b}	117.41 ^{f}	91.23 ^{bc}	15.23 ^{a}	14.23 ^{ab}	136.67 ^{ab}	23.33 ^{cd}	7.91 ^{c}	7.50 ^{bcd}	0.51 ^{a}
7	NPT-7	88.23 ^{b}	118.21 ^{g}	89.43 ^{abc}	14.43 ^{a}	12.70 ^{a}	126.07 ^{ab}	24.28 ^{def}	6.29 ^{b}	6.90 ^{b}	0.47 ^{a}
8	NPT-8	91.00 ^{b}	116.34 ^{e}	92.50 ^{bc}	15.33 ^{a}	15.73 ^{c}	143.97 ^{ab}	23.55 ^{cde}	8.01 ^{c}	7.67 ^{bcd}	0.51^{a}
9	Check (Jyothi)	90.00 ^{b}	113.00 ^{b}	86.13 ^{ab}	14.33 ^{a}	13.10 ^{a}	120.43 ^{a}	21.46 ^{a}	5.18 ^{a}	5.63 ^{a}	0.48 ^{a}
Mean of NPT lines		**86.00**	**114.85**	**90.5**	**15.05**	**13.791**	**136.28**	**23.39**	**7.22**	**7.50**	**0.48**

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Table 7. Mean performance of NPT lines and check variety for different quantitative characters at Thenkurissi, Palghat (*Rabi*, 2005)

S.N	Genotypes	Characters							
		1000- grain weight (g)	L/B ratio	Grain shape	Milling percentage	Head rice recovery (%)	Kernel elongation ratio	Volume expansion ratio	Amylose content (%)
1	NPT-1	24.76 ^{b}	3.40 ^{c}	Slender	73.67 ^{ab}	82.89 ^{abc}	1.65 ^{a}	5.47 ^{a}	16.85 ^{f}
2	NPT-2	25.20 ^{bc}	3.70 ^{d}	Slender	72.10 ^{a}	81.54 ^{ab}	1.66 ^{a}	5.43 ^{a}	10.40 ^{b}
3.	NPT-3	26.73 ^{de}	3.40 ^{c}	Slender	79.20 ^{c}	89.37 ^{de}	1.52 ^{a}	5.75 ^{a}	9.59 ^{a}
4	NPT-4	25.03 ^{bc}	3.20 ^{b}	Slender	73.63 ^{ab}	84.75 ^{bcd}	1.47 ^{a}	4.90 ^{a}	16.73 ^{f}
5	NPT-5	25.47 ^{bc}	3.50 ^{c}	Slender	78.83 ^{c}	84.75 ^{bcd}	1.68 ^{a}	5.33 ^{a}	10.27 ^{b}
6	NPT-6	22.13 ^{a}	3.60 ^{d}	Slender	76.17 ^{bc}	89.56 ^{e}	1.53 ^{a}	4.97 ^{a}	15.90 ^{e}
7	NPT-7	25.83 ^{cd}	2.70 ^{a}	Medium	71.53 ^{a}	90.85 ^{e}	1.71 ^{a}	5.13 ^{a}	13.85 ^{d}
8	NPT-8	28.43 ^{f}	2.92 ^{b}	Medium	74.40 ^{ab}	87.11 ^{de}	1.66 ^{a}	5.13 ^{a}	12.17 ^{c}
9	Jyothi	27.37 ^{e}	3.42 ^{c}	Slender	74.33 ^{ab}	79.60 ^{a}	1.47 ^{a}	4.97 ^{a}	18.93 ^{g}
Mean of NPT lines		**25.45**	**3.33**		**74.94**	**86.35**	**1.76**	**5.26**	**13.22**

All the NPT lines and Jyothi performed uniformly for number of total tillers per plant, harvest index, kernel elongation ratio and volume expansion ratio. Thousand-grain weight was significantly high for NPT-8(28.43g).NPT-2 and NPT-6 exhibited significantly high mean values for L/B ratio (3.70 and 3.60 respectively) and low mean values for NPT-7 and NPT-8 (2.70 and 2.92 respectively, which produced medium sized grains). Significantly high milling percentage was recorded by NPT-3(79.20 per cent) and NPT-5(78.83 per cent).Jyothi had significantly high mean value for amylose content (18.93 per cent) whereas NPT-3 recorded low mean values of 9.59 per cent for amylose content.

At Mathur (Table 8) during *rabi*, 2005 the performance of NPT lines was tested and compared with Jyothi as check variety, in general NPT lines recorded low mean values for days to 50 per cent flowering, days to maturity, number of total tillers per plant, number of productive tillers per plant, number of spikelets per panicle, grain yield .straw yield, 1000-grain yield, kernel elongation ratio, volume expansion ratio and amylose content. On the other hand, panicle length, harvest index, L/B ratio, milling percentage and head rice recovery were high mean values.

NPT-5 had significantly high mean value for days to 50 % flowering (97.21 days).Significantly low numbers of days for maturity was recorded by NPT-4(102.21 days) and NPT-1(113.21 days).Significantly high plant height was exhibited by NPT-5 and NPT-3 (97.67 cm 96.47 cm respectively). All the NPT lines and Jyothi performed uniformly for number of total tillers per plant, number of productive tillers per plant, harvest index, kernel elongation ratio and volume expansion ratio. Number of spikelets per panicle was significantly low for NPT-2(111.67).Jyothi had the shortest panicle length (19.50cm) and was on par with NPT-2(20.28cm).Significantly more grain yield was recorded by NPT-4(6.87 t per ha).With regard to straw yield, NPT-4 and NPT-8 recorded significantly high mean values (7.81 and 7.77 t per ha respectively) and were on par with that of Jyothi (7.27).NPT-6 had significantly low mean value for 1000-grain weight (22.67g). Significantly low L/B ratio (2.80) was noticed in NPT-7, which produced medium sized grains .Jyothi had significantly low mean value (71 per cent) for milling percentage and high mean value for amylose content (22.13 per cent).

Table 8.Mean performances of NPT lines and check variety for different quantitative characters at Mathur, Palghat (*Rabi* , 2005)

S.N	Genotypes	Characters									
		Days to 50 % flowering (days)	Days to maturity (days)	Height of plant (cm)	Number of total tillers per plant	Number of productive tillers per plant	Number of spikelets per panicle	Panicle length(cm)	Grain yield (t per ha)	Straw yield (t per ha)	Harvest index
1	NPT-1	87.00 [a]	113.21 [a]	89.23 [a]	16.47 [a]	12.87 [a]	156.7 [b]	23.95 [cde]	5.62 [a]	6.53 [ab]	0.44 [a]
2	NPT-2	86.67 [a]	114.31 [b]	85.70 [a]	16.23 [a]	13.87 [a]	111.67 [a]	20.28 [ab]	5.28 [a]	6.17 [a]	0.46 [a]
3.	NPT-3	94.00 [b]	123.40 [d]	96.47 [b]	15.57 [a]	13.93 [a]	162.47 [b]	25.63 [e]	5.65 [a]	6.25 [a]	0.47 [a]
4	NPT-4	88.23 [a]	102.21 [a]	89.17 [a]	15.00 [a]	12.37 [a]	176.73 [b]	22.23 [bc]	6.87 [b]	7.81 [c]	0.47 [a]
5	NPT-5	97.21 [c]	124.41 [d]	97.67 [b]	15.93 [a]	13.77 [a]	156.67 [b]	25.22 [de]	5.44 [a]	6.17 [a]	0.49 [a]
6	NPT-6	92.33 [b]	123.33 [d]	88.22 [a]	15.17 [a]	13.23 [a]	155.30 [b]	24.97 [de]	5.37 [a]	5.97 a	0.47 a
7	NPT-7	93.00 [b]	124 .24 [d]	88.07 [a]	14.37 [a]	14.50 [a]	169.57 [b]	23 [cd]	6.12 [a]	6.40 [ab]	0.51 [a]
8	NPT-8	96 [.00b]	123.14 [d]	86.60 [a]	14.10 [a]	14.00 [a]	171.13 [b]	22.07 [bc]	6.13 [a]	7.77 [c]	0.44 [a]
9	Jyothi	94.00 [b]	121.00 [c]	83.87 [a]	16.87 [a]	14.57 [a]	168.90 [b]	19.50 [a]	5.90 [a]	7.27 [bc]	0.44 [a]
Mean of NPT lines		91.80	118.30	90.14	15.36	13.58	158.30	23.42	5.81	6.63	0.47

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Table 8. Mean performance of NPT lines and check variety for different quantitative characters at Mathur, Palghat (*Rabi* , 2005)

S.N	Genotypes	Characters							
		1000 grain weight(g)	L/B ratio	Grain shape	Milling percentage	Head rice recovery (%)	Kernel elongation ratio	Volume expansion ratio	Amylose content (%)
1	NPT-1	25.03^{b}	3.50^{c}	Slender	77.00^{b}	83.33^{abc}	1.61^{a}	5.00^{a}	17.26^{e}
2	NPT-2	24.93^{b}	3.40^{de}	Slender	76.53^{b}	84.15^{abc}	1.55^{a}	5.68^{a}	10.69^{b}
3.	NPT-3	26.13^{c}	3.30^{cd}	Slender	77.20^{b}	80.60^{ab}	1.59^{a}	5.25^{a}	9.58^{a}
4	NPT-4	25.23^{b}	3.40^{de}	Slender	76.10^{b}	75.33^{a}	1.63^{a}	5.57^{a}	17.00^{e}
5	NPT-5	25.37^{bc}	3.50^{c}	Slender	78.50^{b}	76.00^{a}	1.59^{a}	5.60^{a}	10.09^{ab}
6	NPT-6	22.67^{a}	3.30^{cd}	Slender	76.77^{b}	82.34^{abc}	1.48^{a}	5.40^{a}	15.83^{d}
7	NPT-7	27.87^{d}	2.80^{a}	Medium	78.40^{b}	88.67^{bc}	1.58^{a}	5.10^{a}	12.94^{c}
8	NPT-8	29.30^{e}	2.90^{a}	Medium	78.67^{b}	91.00^{c}	1.66^{a}	5.12^{a}	12.25^{c}
9	Jyothi	27.37^{d}	3.17^{b}	Slender	71.00^{a}	82.67^{abc}	1.68^{a}	5.37^{a}	22.13^{f}
Mean of NPT lines		**25.82**	**3.31**		**77.40**	**82.70**	**1.59**	**5.34**	**13.21**

4.1.2 Variability

The extent of genetic variability with respect to different quantitative characters in eight NPT lines and check variety were estimated for three locations viz., Nenmeni, Thenkurissi and Mathur during *rabi,* 2005.The abstract of analysis of variance and variability of different characters are presented in Tables 9, 10 and 11.

At Nenmeni (Table 9) nine genotypes showed significant difference for all the yield attributing characters except number of productive tillers per plant, harvest index and kernel elongation ratio.

At Thenkurissi (Table 10), except for plant height, number of total tillers per plant, number of productive tillers per plant, number of spikelets per panicle and harvest index, all other characters showed significant difference.

Results of ANOVA revealed a highly significant difference among the nine genotypes for 13 different characters at Mathur (Table 11).The characters included days to 50 per cent flowering, days to maturity, plant height, number of spikelets per panicle, panicle length, straw yield , 1000-grain weight, L/B ratio, milling percentage, ,kernel elongation ratio, head rice recovery and amylose content.

Variability parameters like range, mean, Genotypic Coefficient Variation (GCV) and Phenotypic Coefficient of Variation (PCV) computed for characters in all the locations are presented in Tables 12-15.

At Nenmeni (Table 12), days to maturity varied from 108 to 118 days with an average of 112.78 days. The number of productive tillers per plant ranged from 9.33 to 12.17 with mean of 11.19.The number of spikelets per panicle varied between 122.07 to 200.33 with an average of 153.63.Grain yield and straw yield (t per ha) varied from 5.88 to 9.82 and 6.57 to 10.89 respectively. Among the characters studied moderate estimates of GCV was observed for number of spikelets per panicle, panicle length, grain yield. Straw yield (t per ha) and L/B ratio. Number of total tillers per plant, number of

Table 9. Analysis of variance for grain yield and associated characters in NPT lines and check variety (Jyothi) at Nenmeni location, Palghat (*Rabi*, 2005)

Characters	Mean sum of squares		
	Genotype (df = 8)	Replication (df = 2)	Error (df = 16)
Days to 50% flowering (days) X_1	31.33 **	9.0 **	0.00
Days to maturity (days) X_2	53.08 **	6.328 **	3.339
Height of plant (cm) X_3	50.135 **	3.875	9.979
Number of total tillers per plant X_4	1089.22 **	1786.75	922.19
Number of productive tillers per plant X_5	0.742	1.997	1.431
Number of spikelets per panicle X_6	1611.23 **	424.18	451.13
Panicle length (cm) X_7	11.401**	0.7109	.583
Grain yield (t per ha) X_8	6.361**	4.444	0.521
Straw yield (t per ha) X_9	7.563 **	1.164	4.98
Harvest index X_{10}	0.00035	0.00012	0.00025
1000-grain weight (g) X_{11}	11.578 **	2.063	6.817
L/B ratio X_{12}	4.166 **	0.0433**	0.00916
Milling percentage X_{13}	8.649 **	1.562	2.196
Head rice recovery (%) X_{14}	76.026 **	4.609	10.254.
Kernel elongation ratio X_{15}	0.0225	0.238	0.0035
Volume expansion ratio X_{16}	0.42*	0.13*	0.11
Amylose content (%) X_{17}	37.162 **	0.0048	3.861

➢ Significant at 5 % Level * Significant at 1 % Level **

Table10. Analysis of variance for grain yield and associated characters in NPT lines and check variety (Jyothi) at Thenkurissi location, Palghat (*Rabi*, 2005)

Characters	Mean sum of squares		
	Genotype df = 8	Replication df = 2	Error df = 16
Days to 50% flowering (days) X_1	6.04 **	4.33**	6.29
Days to maturity (days) X_2	21.082**	10.109**	0.236
Height of plant (cm) X_3	52.578	2.054	21.946
Number of total tillers per plant X_4	1.224	13.943**	1.30
Number of productive tillers per plant X_5	3.383	11.573**	2.107
Number of spikelets per panicle X_6	298.83	370.73	250.79
Panicle length (cm) X_7	5.327**	1.047	0.355
Grain yield (t per ha) X_8	4.4850 *	0.0761	0.253
Straw yield (t per ha) X_9	3.449 **	3.156**	4.837
Harvest index X_{10}	944.01	0.0035	0.002
1000-grain weight (g) X_{11}	9.630**	0.319	0.311
L/B ratio X_{12}	2.711**	0.0492**	0.0038
Milling percentage X_{13}	21.910**	4.117	4.576
Head rice recovery (%) X_{14}	45.351**	11.062	7.489
Kernel elongation ratio X_{15}	0.565*	0.298*	0.47
Volume expansion ratio X_{16}	0.22*	0.102*	0.143
Amylose content (%) X_{17}	34.923**	1.037	0.159

- Significant at 5 % Level * Significant at 1 % Level **

Table11. Analysis of variance for grain yield and associated characters in NPT lines and check variety (Jyothi) at Mathur location, Palghat (*Rabi*, 2005)

Characters	Mean sum of squares		
	Genotype (df = 8)	Replication (df = 2)	Error (df = 16)
Days to 50% flowering(days) X_1	43.87 **	1.14	4.23
Days to maturity(days) X_2	169.98**	0.7187	1.201
Height of plant(cm) X_3	65.125**	11.156	11.045
Number of total tillers per plant X_4	2.710	0.524	2.917
Number of productive tillers per plant X_5	1.612	0.345	1.752
Number of spikelets per panicle X_6	905.39 *	47.968	294.89
Panicle length (cm) X_7	14.139**	2.813	1.759
Grain yield (t per ha)X_8	0.753	0.481	0.336
Straw yield (t per ha) X_9	1.545**	0.0473	2.705
Harvest index X_{10}	0.0014	0.0002	0.0009
1000-grain weight (g) X_{11}	11.411**	0.805*	0.199
L/B ratio X_{12}	0.1375**	0.0532**	0.0033
Milling percentage X_{13}	16.207*	0.882	5.810
Head rice recovery (%) X_{14}	79.004 *	5.734	30.322
Kernel elongation ratio X_{15}	0.0011**	0.20	0.004
Volume expansion ratio X_{16}	1.36**	0.107	0.095
Amylose content (%) X_{17}	35.990**	0.045	0.189

- Significant at 5 % Level * Significant at 1 % Level **

Table 12. Variability parameters in NPT lines and check variety (Jyothi) at Nenmeni, Palghat (*Rabi,* 2005)

S.N	Characters	Range	Mean	GCV (%)	PCV (%)
1.	Days to 50 % flowering (days)	81.24 – 89.31	85.22 ± 0.00	3.79	3.79
2.	Days to maturity (days)	106.43-118.10	112.78 ±.472	3.72	3.75
3.	Height of plant (cm)	85.20-98.87	93.35 ± 2.58	3.92	5.18
4.	Number of total tillers per plant	10.82 – 13.30	12.79 ± 1.00	8.40	12.74
5.	Number of productive tillers per plant	9.33-12.17	11.19 ±.977	3.88	11.38
6	Number of spiklets per panicle	122.07-200.30	153.63 ±17.342	12.80	18.84
7	Panicle length (cm)	20.48-25.53	23.45 ±0.623	16.90	8.73
8	Grain yield (t per ha)	5.88-9.82	8.26 ±0.59	16.90	19.03
9	Straw yield (t per ha)	6.57-10.89	9.20 ±0.576	16.68	18.36
10	Harvest index	0.45-0.48	.472 ±0.013	1.20	3.60
11	1000-grain weight (g)	22.10 - 29.10	26.043 ±0.674	7.32	7.98
12	L/B ratio	2.80-29.10	3.344 ±0.0782	11.02	11.39
13	Milling percentage	75.73-80.67	77.40 ±1.21	1.89	2.69
14	Head rice recovery (%)	77.07-90.51	84.19 ±2.61	5.56	6.74
15	Kernel elongation ratio	1.47-1.71	1.61±0.05	4.93	6.15
16	Volume expansion ratio	4.40-5.64	5.21 ±0.27	6.18	8.79
17	Amylose content (%)	9.55-18.74	13.78 ±0.51	25.40	25.80

productive tillers per plant, number of spikelets per panicle, grain yield, straw yield and L/B ratio recorded for moderate PCV whereas amylose content exhibited the highest values of GCV and PCV (Table 12).

At Thenkurissi (Table 13) for days to 50 per cent flowering, the range of variation was from 79 to 91 days with an average of 86.44 days. With respect to plant height, the variability ranged from 82.58 to 97.07cm, with a mean of 90.10 cm.Grain yield and straw yield(t per ha) varied from 5.11 to 8.01 and 5.63 to 8.57, respectively. Among grain quality characters, milling percentage varied from 71.53 to 79.20 per cent with a mean of 74.87 per cent. The mean amylose content ranged from 9.59 to 18.93 per cent, average being 13.85 per cent.

Among the characters studied moderate estimates of GCV was observed for grain yield, straw yield (t per ha) and kernel elongation ratio and moderate estimates of PCV for number of productive tillers per plant, number of spikelets per panicle, grain yield and straw yield and harvest index. Kernel elongation ratio and amylose content were exhibiting high values of GCV and PCV.

At Mathur (Table 14) number of total tillers per plant varied from 14.07 to 16.87 with an average of 15.52. With regard to panicle length, the variability ranged from 19.50 to 25.63, average being 22.98 cm. Grain yield and straw yield varied from 5.28 to 6.87 and 5.97 to 7.81 respectively. The study for estimates of coefficient of variation revealed moderate PCV for number of total tillers per plant, number of spikelets per panicle, panicle length, grain yield and straw yield and volume expansion ratio and high PCV for amylose content.

4.2 Heritability, Genetic advance and Genetic gain

Genetic parameters like heritability, genetic advance and genetic gain estimated for yield attributes at Nenmeni, Thenkurissi and Mathur (*rabi,* 2005) are presented in Tables15-17.

Table 13. Variability parameters in NPT lines and check variety (Jyothi) at Thenkurissi, Palghat (*Rabi*, 2005)

S.N	Characters	Range	Mean	GCV (%)	PCV (%)
1	Days to 50 % flowering (days)	79.00 – 91.00	86.44 ± 2.5	4.91	5.71
2	Days to maturity (days)	109.14-118.21	114.44 ± 0.39	2.30	2.34
3	Height of plant (cm)	82.58-97.07	90.10 ± 3.83	3.55	6.29
4	Number of total tillers per plant	14.33-15.90	14.97 ± 0.91	0.21	7.49
5	Number of productive tillers per plant	12.60-15.73	13.71 ± 1.12	4.76	11.61
6.	Number of spiklets per panicle	120.43-152.63	134.51 ± 12.93	2.97	12.14
7	Panicle length (cm)	21.46-25.20	23.20 ± 0.486	5.55	6.12
8	Grain yield (t per ha)	5.11-8.01	6.99 ± 0.41	16.99	18.45
9	Straw yield (t per ha)	5.63-8.57	7.29 ± 0.57	13.63	16.63
10	Harvest index	0.46-0.51	0.48 ± 0.038	6.59	11.86
11	1000-grain weight (g)	22.13-28.43	25.66 ± 0.45	6.87	7.20
12	L/B ratio	2.70-3.70	3.33 ± 0.51	8.95	9.14
13	Milling percentage	71.53-79.20	74.87 ± 1.74	3.21	4.30
14	Head rice recovery (%)	79.60-90.85	85.60 ± 2.23	4.15	5.24
15	Kernel elongation ratio	1.47-2.88	1.75 ± 0.56	10.10	40.59
16	Volume expansion ratio	4.9-5.75	5.25 ± 0.31	3.04	7.83
17	Amylose content (%)	9.59-18.93	13.85 ± 0.33	24.57	24.73

Table14. Variability parameters in NPT lines and check variety (Jyothi) at Mathur, Palghat (*Rabi* , 2005)

S.N	Characters	Range	Mean	GCV (%)	PCV (%)
1.	Days to 50 % flowering(days)	86.67 – 97.21	92.03±1.67	3.95	4.54
2	Days to maturity (days)	102.21-124.24	118.59 ±.89	6.32	6.39
3	Height of plant(cm)	83.97-97.67	89.44 ±2.71	4.75	6.03
4	Number of total tillers per plant	14.07-16.87	15.52 ±1.40	0.20	11.01
5.	Number of productive tillers per plant	12.37-14.57	13.69 ±1.10	0.23	9.68
6	Number of spiklets per panicle	111.67-176.73	159.46 ±14.02	8.95	14.00
7	Panicle length(cm)	19.50-25.63	22.98 ±1.10	8.84	10.56
8	Grain yield (t per ha)	5.28-6.87	5.82±0.473	6.41	11.84
9	Straw yield (t per ha)	5.97-7.81	6.70±0.425	9.73	12.44
10	Harvest index	0.44-0.51	0.47 ±0.025	2.74	7.07
11	1000-grain weight(g)	22.67-29.30	25.99 ±.364	7.44	7.63
12	L/B ratio	2.80-3.50	3.29 ±0.047	6.42	6.65
13	Milling percentage	71-78.67	76.68 ±1.97	2.43	3.97
14	Head rice recovery (%)	75.33- 91.00	82.67 ±1.45	4.87	8.25
15	Kernel elongation ratio	1.48 - 1.68	1.59 ±0.50	2.97	4.86
16	Volume expansion ratio	5.00-5.6.80	5.34±0.45	0.59	10.47
17	Amylose content (%)	9.58-18.83	13.83 ±0.355	24.98	25.17

Table 15. Estimation of genetic parameters for grain yield and its characters in NPT lines and check variety at Nenmeni, Palghat (*Rabi*, 2005)

S.N	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1.	Days to 50 % flowering(days)	100.00	6.66	7.81
2	Days to maturity (days)	98.10	8.56	7.59
3	Height of plant (cm)	57.30	5.70	7.49
4	Number of total tillers per plant	43.50	1.46	11.42
5	Number of productive tillers per plant	11.60	0.31	2.17
6	Number of spiklets per panicle	46.20	27.52	6.80
7	Panicle length (cm)	86.10	3.63	15.47
8	Grain yield (t per ha)	78.90	2.55	30.90
9	Straw yield (t per ha)	82.50	2.87	31.19
10	Harvest index	11.10	0.00	0.00
11	1000-grain weight(g)	84.20	3.60	13.82
12	L/B ratio	93.70	0.73	21.85
13	Milling percentage	49.50	2.12	2.73
14	Head rice recovery (%)	68.10	7.96	9.45
15	Kernel elongation ratio	64.30	0.13	8.10
16	Volume expansion ratio	79.40	0.47	9.02
17	Amylose content (%)	96.90	7.10	51.15

At Nenmeni, high estimates (>60 per cent) of heritability were noticed for days to 50 per cent flowering (100 per cent), days to maturity (98.1 per cent), amylose content (96.9 per cent), L/B ratio (93.7per cent), panicle length (86.1per cent), 1000-grain weight (84.2 per cent), straw yield (82.5per cent), volume expansion ratio (79.4 per cent), grain yield (78.9 per cent), head rice recovery (68.1per cent) and kernel elongation ratio (64.3 per cent). Heritability values were moderate in case of plant height (57.3 per cent), milling percentage (49.5per cent), number of spikelets per panicle (46.2per cent) and number of total tillers per plant (43.5 per cent).

The highest genetic advance of 27.52 per cent was observed in case of number of spikelets per panicle. High estimates of genetic gain were noticed for amylose content (51.15 per cent), straw yield (31.19 per cent), grain yield (30.9 per cent), L/B ratio (21.85 per cent) and High heritability coupled with high genetic gain (>20 per cent) was exhibited by grain yield, straw yield, L/B ratio and amylose content (Table15).

At Thenkurissi, (Table 16) high estimates of heritability (>60 per cent) were noticed for amylose content (98.6 per cent), days to maturity (96.7 per cent), L/B ratio (95.8 per cent), 1000-grain weight (90.9 per cent), grain yield (84.8 per cent), volume expansion ratio (83.7 per cent), panicle length (82.4 per cent), days to 50 per cent flowering (74.1 per cent), kernel elongation ratio (70.6 per cent), straw yield (67.1 per cent) and head rice recovery (62.8 per cent) .Maximum heritability of 98.6 per cent was noticed for amylose content and the minimum heritability (0 to 30 per cent) was noticed for number of total tillers per plant (0.1 per cent), harvest index (3.10 per cent), number of spikelets per panicle (6.00 per cent) and number of productive tillers per plant (16.8 per cent).

High estimates of heritability coupled with high genetic gain was observed in case of grain yield, straw yield, volume expansion ratio and amylose content. Low estimates of genetic gain (<10 per cent) was recorded for number of spikelets per panicle (1.50 per cent), number of productive tillers per plant (4.00 per cent), plant height (4.11 per cent),

Table 17. Estimation of genetic parameters for grain yield and its characters in NPT lines and check variety at Mathur, Palghat (*Rabi*, 2005)

Sl.No	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1.	Days to 50 % flowering(days)	75.70	6.52	7.00
2.	Days to maturity (days)	15.00	15.29	12.89
3.	Height of plant(cm)	70.10	6.89	7.70
4.	Number of total tillers per plant	0.00	0.00	0.00
5.	Number of productive tillers per plant	0.10	0.00	0.00
6.	Number of spiklets per panicle	40.80	18.78	11.77
7.	Panicle length (cm)	97.90	3.50	15.23
8.	Grain yield (t per ha)	29.30	0.42	7.21
9.	Straw yield (t per ha)	61.10	1.05	15.67
10.	Harvest index	15.00	0.01	2.17
11.	1000-grain weight(g)	62.00	3.88	14.93
12.	L/B ratio	94.90	0.42	12.76
13.	Milling percentage	93.00	2.34	3.00
14.	Head rice recovery (%)	37.40	4.90	5.90
15.	Kernel elongation ratio	37.90	0.06	3.77
16.	Volume expansion ratio	30.00	1.21	22.79
17.	Amylose content (%)	81.70	7.06	51.12

Table 16. Estimation of genetic parameters for grain yield and its characters in NPT lines and check variety at Thenkurissi, Palghat(*Rabi*, 2005)

S.N	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1.	Days to 50 % flowering (days)	74.10	7.53	8.71
2.	Days to maturity (days)	96.70	5.34	4.66
3.	Height of plant (cm)	31.80	3.71	4.11
4.	Number of total tillers per plant	0.10	0.00	0.00
5.	Number of productive tillers per plant	16.80	0.55	4.0
6.	Number of spiklets per panicle	6.00	2.02	1.50
7.	Panicle length (cm)	82.40	2.41	10.44
8.	Grain yield (t per ha)	84.80	2.25	32.18
9.	Straw yield (t per ha)	67.10	1.68	23.00
10.	Harvest index	3.10	0.04	8.50
11.	1000-grain weight (g)	90.90	3.46	13.48
12.	L/B ratio	95.80	0.60	18.01
13.	Milling percentage	55.80	3.70	4.90
14.	Head rice recovery (%)	62.80	5.80	6.77
15.	Kernel elongation ratio	70.60	0.10	7.00
16.	Volume expansion ratio	83.70	1.11	22.42
17.	Amylose content (%)	98.60	6.96	50.25

Table 17. Estimation of genetic parameters for grain yield and its characters in NPT lines and check variety at Mathur, Palghat (*Rabi*, 2005)

Sl.No	Characters	Heritability (%)	Genetic advance	Genetic gain (%)
1.	Days to 50 % flowering(days)	75.70	6.52	7.00
2.	Days to maturity (days)	15.00	15.29	12.89
3.	Height of plant(cm)	70.10	6.89	7.70
4.	Number of total tillers per plant	0.00	0.00	0.00
5.	Number of productive tillers	0.10	0.00	0.00
6.	Number of spiklets per panicle	40.80	18.78	11.77
7.	Panicle length (cm)	97.90	3.50	15.23
8.	Grain yield (t per ha)	29.30	0.42	7.21
9.	Straw yield (t per ha)	61.10	1.05	15.67
10.	Harvest index	15.00	0.01	2.17
11.	1000-grain weight(g)	62.00	3.88	14.93
12.	L/B ratio	94.90	0.42	12.76
13.	Milling percentage	93.00	2.34	3.00
14.	Head rice recovery (%)	37.40	4.90	5.90
15.	Kernel elongation ratio	37.90	0.06	3.77
16.	Volume expansion ratio	30.00	1.21	22.79
17.	Amylose content (%)	81.70	7.06	51.12

days to maturity (4.66 per cent), milling percentage (4.90 per cent), head rice recovery (6.77 per cent), kernel elongation ratio (7.00 per cent) and harvest index (8.50 per cent).

At Mathur (Table 17) among the yield attributing characters, high estimates of heritability (>60 per cent) were noticed for panicle length (97.90 per cent), L/B ratio (94.90 per cent), milling percentage (93.00 per cent),amylose content (81.70 per cent) ,days to 50 per cent flowering (75.70 per cent), plant height (70.10 per cent), 1000-grain weight (62.00 per cent), and straw yield (61.10 per cent). High heritability along with low genetic gain was noticed in case of days to 50 per cent flowering, plant height and milling percentage. High estimates of genetic gain (>20 per cent) was recorded for volume expansion ratio (22.79 per cent) and amylose content (51.12) whereas low genetic gain was noticed in case of number of total tillers per plant (0), number of productive tillers per plant(0), harvest index (2.17 per cent), milling percentage (3.00), kernel elongation ratio (3.77 per cent), head rice recovery (5.90 percent), days to 50 per cent flowering (7.00 per cent), grain yield (7.21 percent) and height of plant (7.70 per cent).

4.3 Genotypic correlation

The association of grain yield with other characters was estimated by genotypic correlation coefficients (Tables18- 20), and results are presented below.

At Nenmeni, (Table 18) days to 50 per cent flowering exhibited significant positive correlation with days to maturity (0.7781) and grain yield (0.3835). Days to maturity was positively correlated with days to 50 per cent flowering (0.7781) and 1000-grain weight (0.5426) whereas number of spikelets per panicle (-0.4142) exhibited significant negative correlation (-0.4142) with days to maturity.

Plant height was positively correlated with panicle length (0.5668), grain yield (0.4209) and straw yield (0.4091) and was negatively correlated with number of total tillers per panicle (-0.3835).

Table 18. Genotypic correlation coefficients between grain yield and its components in NPT lines and check variety (Jyothi) at Nenmeni, Palghat (*Rabi*, 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
1	Days to 50% flowering (days) X_1	**1.000**	0.7781**	-0.179	0.1353	-0.3590	0.0546	0.3835*	-0.3447	0.3304
2	Days to maturity (days) X_2		**1.000**	-0.1459	0.1544	-0.4142*	0.0260	-0.2675	-0.3324	0.5426**
3	Height of plant (cm) X_3			**1.000**	-0.3835*	0.1675	0.5668**	0.4209*	0.4091*	0.2008
4	Number of total tillers per plants X_4				**1.000**	0.1087	-0.2985	-0.0131	0.0053	-0.0056
5	Number of spikelets per panicle X_5					**1.000**	-0.1309	0.5598**	0.6293**	-0.1747
6	Panicle length (cm) X_6						**1.000**	0.3801*	0.3273	-0.1758
7	Grain yield (t per ha) X_7							**1.000**	0.9847**	-0.2497
8	Straw yield (t per ha) X_8								**1.000**	-0.3175
9	1000-grain weight (g) X_9									**1.000**

Table 19. Genotypic correlation coefficients between grain yield and its components in NPT lines and check variety (Jyothi) at Thenkurissi (*Rabi*, 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
1	Days to 50% flowering (days) X_1	**1.000**	0.5376**	0.3047	-0.1564	-0.0520	0.4004*	0.3691*	0.0324	0.2589
2	Days to maturity (days) X_2		**1.000**	0.4378*	-0.0431	0.2276	0.5755**	0.2393	0.0751	-0.0162
3	Height of plant (cm) X_3			**1.000**	0.0196	0.3100	0.4853**	0.2476	0.2104	0.0417
4	Number of total tillers per plants X_4				**1.000**	-0.3375	-0.2871	0.2125	0.4378*	-0.1059
5	Number of spikelets per panicle X_5					**1.000**	0.3008	0.3916*	0.4160*	-0.0182
6	Panicle length (cm) X_6						**1.000**	0.4306*	0.2578	0.0532
7	Grain yield (t per ha) X_7							**1.000**	0.8433**	-0.0701
8	Straw yield (t per ha) X_8								**1.000**	0.0282
9	1000-grain weight (g) X_9									**1.000**

Significant at 5 % level *　　　　**Significant at 1 % level ****

Significant positive genotypic correlation of grain yield was observed with days to 50 % flowering (0.3835), plant height (0.4209), number of spikelets per panicle (0.5598), panicle length (0.3801) and straw yield (0.9847). Straw yield was positively correlated with plant height (0.4091), number of spikelets per panicle (0.6293) and grain yield (0.9847).

At Thenkuruissi (Table 19), significant positive genotypic correlation of days to 50 per cent flowering was observed with days to maturity (0.5376), panicle length (0.4004) and grain yield (0.3691). Days to maturity was positively correlated with days to 50 percent flowering (0.5376), plant height (0.4378) and panicle length (0.5755).

Plant height was positively correlated with days to maturity (0.4378) and panicle length (0.4853). Significant positive genotypic correlation of panicle length was observed with days to 50 per cent flowering (0.4004), days to maturity (0.5755), plant height (0.4853) and grain yield (0.4306).

Significant positive genotypic correlation of grain yield was observed with days to 50 per cent flowering (0.3691), number of spikelets per panicle (0.3916), panicle length (0.4306) and straw yield (0.8433). Straw yield was positively correlated with number of total tillers per plant (0.4378), number of spikelets per panicle (0.4160) and grain yield (0.8433).

At Mathur (Table 20), days to 50 % flowering was positively correlated with days to maturity (0.7050) and 1000-grain weight (0.4038) and it was showed negative correlation with grain yield (-0.4017). Days to maturity was positively correlated with days to 50 per cent flowering (0.7050) and negatively correlated with grain yield (-0.3648). Plant height was positively correlated with panicle length (0.6664) and it was negatively correlated with straw yield (-0.3775).

Significant positive correlation was observed for grain yield with number of spikelets per panicle (0.3693), straw yield (0.7928) and 1000-grain weight (0.3746) and it showed negative correlation with days to 50 per cent flowering (-0.4017), days to

Table 20. Genotypic correlation coefficients between grain yield and its components in NPT lines and check variety(Jyothi) at Mathur (*Rabi*, 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
1	Days to 50% flowering(days) X_1	**1.000**	0.7050**	0.2922	-0.0732	0.2771	0.2749	-0.4017*	-0.0015	0.4038*
2	Days to maturity (days) X_2		**1.000**	0.1655	-0.0701	0.0113	0.2906	-0.3648*	-0.3737	0.2578
3	Height of plant(cm) X_3			**1.000**	0.0842	0.0810	0.6664**	-0.2295	-0.3775*	-0.1703
4	Number of total tillers per plants X_4				**1.000**	-0.1385	0.0690	-0.3059	-0.2386	-0.2847
5	Number of spikelets per panicle X_5					**1.000**	0.1280	0.3693*	0.3866*	0.3193
6	Panicle length(cm) X_6						**1.000**	-0.4123*	-0.4481*	-0.3507
7	Grain yield (t per ha) X_7							**1.000**	0.7928**	0.3746*
8	Straw yield (t per ha) X_8								**1.000**	0.4991**
9	1000-grain weight(g) X_9									**1.000**

Significant at 5 % level *　　　　**Significant at 1 % level ****

maturity (-0.3648) and panicle length (-0.4123). Straw yield was positively correlated with number of spikelets per panicle (0.3866), grain yield (0.7928) and 1000-grain weight (0.4991) whereas plant height (-0.3775) and panicle length (-0.4481) exhibited negative correlation.

4.4 Path analysis

Path analysis is an effort to assess the magnitude of attribution of various agro-morphological characters to yield in the form of cause and effect. Tables 21 to 23 revealed the result of direct and indirect effect of various traits to grain yield.

At Nenmeni (Table 21) the estimates of path coefficients for nine component traits indicated that maximum positive direct effect on grain yield was shown by straw yield (1.0800) whereas maximum negative effect was shown by number of spikelets per panicle(-0.0989).The low positive effect was shown by days to 50 per cent flowering (0.0549). Days to 50 per cent flowering, days to maturity, plant height, number of spikelets per panicle and panicle length had high positive indirect effect on grain yield through straw yield.

At Thenkurissi (Table 22), among the quantitative components characters involved, straw yield had high direct effect (0.8259) on grain yield. Whereas maximum negative effect was shown by 1000-grain weight (-0.1472). The least positive effect is shown by days to maturity (0.0401) and least negative effect is shown by number of total tillers per plant (-0.0004). Number of total tillers per plant had high positive indirect effect on grain yield through straw yield.

At Mathur (Table 23), the estimates of path analysis revealed that maximum positive direct effect on grain yield was exhibited by straw yield (0.6965), whereas maximum negative effect was shown by days to maturity (-0.2311).The least positive effect is showed by number of spikelets per panicle and least negative effect on grain

Table 21. Direct and indirect effect of eight characters on grain yield at Nenmeni *(Rabi,* 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	RG
1	Days to 50% flowering (days) X_1	**-0.0530**	0.0427	0.0043	-0.0027	0.0355	-0.003	-0.3723	0.0223	0.3835
2	Days to maturity(days) X_2	-0.0412	**0.0549**	0.0035	-0.0031	0.0410	-0.0001	-0.3590	0.0366	-0.2675
3	Height of plant(cm) X_3	0.0095	-0.0080	**-0.0239**	0.0076	-0.0166	-0.0031	0.4418	0.0135	0.4209
4	Number of total tillers per plant X_4	-0.0072	0.0085	0.0091	**-0.0198**	-0.0107	0.0016	0.0057	-0.0004	-0.0131
5	Number of spikelets per panicle X_5	0.0190	-0.0227	-0.0014	-0.0021	**0.0989**	0.0007	0.6796	-0.0118	0.5598
6	Panicle length (cm) X_6	-0.0029	0.0014	-0.0182	0.0059	0.0129	**-0.0054**	0.3535	-0.0118	0.3801
7	Straw yield (t per ha) X_7	0.0183	-0.0182	0.0098	-0.0001	-0.0622	-0.0018	**1.0800**	-0.0214	0.9847
8	1000 grain weight (g) X_8	-0.0175	0.0298	-0.0048	0.0001	0.0173	0.0010	-0.3429	**0.0674**	-0.2497

Table 22. Direct and indirect effect of eight characters on grain yield at Thenkurissi *(Rabi,* 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	RG
1	Days to 50% flowering (days) X_1	**0.2420**	0.0216	-0.0200	0.0001	-0.0115	-0.0117	0.0267	-0.0381	0.3691
2	Days to maturity(days) X_2	0.1301	**0.0401**	-0.0288	0.0000	0.0502	-0.0167	0.0620	0.0024	0.2393
3	Height of plant(cm) X_3	0.0737	0.0176	**-0.0657**	0.0000	0.0684	-0.0141	0.1738	-0.0061	0.2476
4	Number of total tillers per plant X_4	-0.0379	-0.0017	-0.0013	**-0.0004**	-0.0745	0.0084	0.3043	0.0156	0.2125
5	Number of spikelets per panicle X_5	-0.0126	0.0091	-0.0204	0.0001	**0.2207**	-0.0088	0.1206	0.0027	0.3916
6	Panicle length (cm) X_6	0.969	0.231	-0.0319	0.0001	0.664	**-0.0291**	0.2129	-0.0078	0.4306
7	Straw yield (t per ha) X_7	0.0078	0.0030	-0.0138	-0.0001	0.322	-0.0075	**0.8259**	-0.0024	0.8433
8	1000- grain weight(g) X_8	0.0627	-0.0006	-0.0027	0.0000	-0.0040	-0.0015	0.0233	**-0.1472**	-0.0701

Table 23. Direct and indirect effect of eight characters on grain yield at Mathur *(Rabi,* 2005)

S.N	Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	RG
1	Days to 50% flowering (days) X_1	**0.0499**	-0.1629	-0.0314	0.0095	0.0096	0.0719	-.0010	0.0371	-0.4017
2	Days to maturity(days) X_2	0.0352	**-0.2311**	-0.0178	0.0091	0.0004	0.0760	-.2603	0.0237	-0.3648
3	Height of plant(cm) X_3	0.0146	-0.0383	**-0.1073**	-0.0110	0.0028	0.1743	-0.2490	-0.0156	-0.2295
4	Number of total tillers per plant X_4	0.0037	0.0162	-0.0090	**-0.1303**	-0.0048	0.0180	-0.1662	-0.0261	-0.3059
5	Number of spikelets per panicle X_5	0.0138	-0.0026	-0.0087	0.0181	**0.0346**	0.335	0.2414	0.0293	0.3693
6	Panicle length (cm) X_6	0.0137	-0.0672	-0.00715	-0.0090	0.0044	**0.2615**	-0.3121	-0.0322	-0.4123
7	Straw yield (t per ha) X_7	-0.0001	0.0864	0.0384	0.0311	0.0120	-0.1172	**0.6965**	0.0458	0.7928
8	1000 grain weight (g) X_8	0.0201	-0.0596	0.0183	0.0371	0.011.	-0.0917	0.3476	**0.0918**	0.3746

yield was shown by plant height (-0.1073).Panicle length and 1000-grain weight had high positive indirect effect on grain yield through straw yield.

4.5 GENOTYPE x ENVIRONMENT INTERACTION

4.5.1 Pooled ANOVA

The analysis of variance of genotypes in relation to the environment was carried out using eight NPT lines and Jyothi as check variety at three different locations. Pooled analysis of variance for 17 characters in nine genotypes are shown in Table 24.

Analysis of variance revealed that days to 50 % flowering, days to maturity, plant height, panicle length,1000-grain weight ,L/B ratio, head rice recovery, kernel elongation ratio, volume expansion ratio and amylose content showed significant difference among genotypes tested. With respect to variance due to environment, days to 50 % flowering, days to maturity, plant height, number of total tillers per plant, number of productive tillers per plant, number of spikelets per panicle, grain yield, straw yield, kernel elongation ratio and volume expansion ratio showed significant difference.

Genotype x environment (G X E) component was found significant for days to maturity, grain yield, straw yield, L/B ratio, kernel elongation ratio, and volume expansion ratio. Environment (linear) was significant for days to 50 per cent flowering, days to maturity, plant height, number of total tillers per plant, number of productive tillers per plant, number of spikelets per panicle, grain yield , straw yield , 1000-grain yield, milling percentage, head rice recovery, kernel elongation ratio and volume expansion ratio indicating that the environments tested differed significantly. G x E (linear) was significant for days to maturity,1000-grain weight, kernel elongation ratio, volume expansion ratio and amylose content indicating that the significant difference among genotypes for these characters was due to linear response of environments.

Table 24. Pooled analysis of variance for yield and its components at three locations in Palghat (*Rabi*, 2005)

S.N	Characters	Mean sum of squares of					
		Genotypes	Environments	G X E	ENV (Linear)	G X E (Linear)	Pooled deviation
1	Days to 50 % flowering (days)	38.492**	118.80**	3.3575	237.63**	4.12	2.302
2	Days to maturity (days)	52.59*	80.67*	14.39**	161.39**	21.60*	6.37**
3	Plant height (cm)	45.346**	39.50**	5.30	78.99**	3.065	6.70
4	Number of total tillers per plant	1.35	18.79**	0.803	37.58**	0.84	0:67
5	Number of productive tillers t per plant	.5083	18.94**	0.9114	37.89**	1.1855	0.566
6	Number of spikelets per panicle	230.92	1532.55*	353.78	3065.18*	209.01	443.14**
7	Grain yield (t per ha)	1.84	13.34**	1.012**	26.68**	1.291	0.652**
8	Straw yield (t per ha)	1.7387	15.328**	1.223**	30.655**	1.7488	0.6213**
9	Harvest index	0.000215	0.000328	0.000345	0.000656	0.0005	0.00017
10	Panicle length (cm)	9.11**	0.4999	0.586	0.996	0.469	0.626*
11	1000 grain weight (g)	10.40**	0.3845	0.232	0.7644**	0.363*	0.090
12	L/B ratio	0.200**	0.0057	0.0375**	0.011	0.045	0.026**
13	Milling percentage	4.22	15.29	5.68	30.60*	4.868	5.77**
14	Head rice recovery (%)	44.08*	19.25	11.35	38.54**	15.98	5.97
15	Kernel elongation ratio	0.078*	0.064*	0.06*	0.122**	0.12**	0.0034*
16	Volume expansion ratio	0.12*	0.039*	0.077*	0.079*	0.095*	0.052*
17	Amylose content (%)	35.83**	0.0121	0.0959	0.0233	0.169**	0.0198

4.5.2 *Stability for yield and yield contributing characters*

The significance of G x E interaction indicated the importance for estimating the stability parameters. The stability parameters like mean, regression coefficient and mean square deviation for each character are presented in Table 25.

4.5.2.1 *Days to 50 % flowering*

Stability parameters for this character revealed that NPT-2 had lowest number of days to 50 % flowering (82.56 days) with regression coefficient of (0.90) and mean square deviation of -0.47 while Jyothi had more number of days for 50 percent flowering (91.00days) with regression coefficient of 0.73 and mean square deviation of –1.16.

4.5.2.2 *Days to maturity*

Among the NPT lines, NPT -4 had recorded lowest number of days to maturity (106.33) with a regression coefficient of -1.16 and low mean square deviation of 0.44.NPT-7 had more number of days to maturity (119.67) with a regression coefficient of 1.25 and mean square deviation of 0.45.

4.5.2.3 *Plant height*

The standard check variety(Jyothi) recorded lowest mean plant height (85.07cm) with regression coefficient of 0.14 and mean square deviation of -2.35.Amomg NPT lines, NPT-5 had highest mean plant height 97.68cm with a regression coefficient of 0.24 and mean square deviation of -4.49.

4.5.2.4 *Number of total tillers per plant*

Stability parameter for this character revealed that the check variety had the maximum mean value of 15.60 with a regression coefficient of 0.17 and mean square deviation of 2.46. Among NPT lines, NPT-8 had a low mean value of 13.41 with regression coefficients of 1.44 and mean square deviation of 1.56.

Table 25. Analysis of G X E interaction in eight NPT lines and check variety (Jyothi) in 17 different characters at three locations in Palghat (*Rabi*, 2005)

Genotypes	Days to 50 % flowering (days)			Days to maturity (days)			Plant height (cm)		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	83.00	0.94	-0.49	112.33	0.37	6.00	91.49	1.06	-3.72
NPT-2	82.56	0.90	-0.47	112.67	0.46	0.62	88.57	1.50	-3.91
NPT-3	90.33	0.88	-1.16	118.67	1.06	12.16	95.95	1.05	6.17
NPT-4	84.44	0.89	1.08	106.33	-1.16	0.44	88.01	1.50	24.43
NPT-5	89.00	2.02	5.26	115.67	2.64	3.49	97.68	0.24	-4.49
NPT-6	89.67	0.69	0.55	116.78	2.15	6.17	90.16	0.47	-1.00
NPT-7	89.11	0.97	-0.49	119.67	1.25	0.45	90.26	1.28	-4.63
NPT-8	92.00	0.99	-0.84	118.00	1.44	0.87	91.45	1.77	6.82
Check (Jyothi)	91.00	0.73	-1.16	117.33	0.79	21.39	85.07	0.14	-2.35

Genotypes	Number of total tillers per plant			Number of productive tillers per plant			Number of spikelets per panicle		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	14.77	1.70	-0.56	12.18	0.90	-0.58	144.37	0.74	-49.03
NPT-2	15.03	1.24	-0.57	13.11	1.22	-0.46	142.19	-0.05	1495.90
NPT-3	14.13	1.16	-0.56	13.27	1.16	-0.43	152.65	1.11	-104.11
NPT-4	14.08	0.74	-0.59	12.22	0.31	-0.56	167.17	2.56	670.52
NPT-5	14.64	0.87	-0.33	12.79	0.77	-0.35	156.13	0.21	-103.82
NPT-6	14.42	0.91	-0.46	13.06	0.81	-0.11	147.63	0.75	-110.76
NPT-7	13.74	0.77	-0.51	12.80	0.95	1.08	145.72	1.51	83.79
NPT-8	13.41	1.44	1.56	13.04	2.22	0.71	149.83	0.69	451.63
Check (Jyothi)	15.60	0.17	2.46	13.28	0.66	0.51	137.13	1.48	657.32

4.5.2.5 *Number of productive tillers per plant*

Jyothi had the maximum mean value of 13.28 with regression coefficient of 0.66 and mean square deviation of 0.51. The NPT-1 had low mean value of 12.18 with a regression coefficient of 0.90 and mean square deviation -0.58.

4.5.2.6 *Number of spikelets per panicle*

Maximum number of spikelets per panicle was observed for NPT-4(167.17) with a regression coefficient of 2.56 and mean square deviation of 670.52.The local check (Jyothi) recorded lowest mean value of 137.13 with regression coefficient of 1.48 and mean square deviation of 657.32.

4.5.27 *Grain yield (t per ha)*

Stability parameters had indicated that NPT lines did not differ significantly for grain yield. However, mean grain yield was maximum for NPT-3(7.65) with a regression coefficient of 1.65 and mean square deviation of -0.12.Jyothi gave a mean value of 5.65 with a zero regression coefficient and mean square deviation of 0.22.

4.5.2.8 *Straw yield (t per ha)*

NPT-3 recorded maximum straw yield of 8.49 with a regression coefficient of 1.60 and mean square deviation of 0.85.Jyothi had a low mean value of 6.49 with regression coefficient of -0.09 and mean square deviation of 1.18.

4.5.2.9 *Harvest index*

NPT-5 and NPT-7 had recorded high mean value of 0.49 with a regression coefficient of -0.37 and -3.01 respectively and zero mean square deviation. All the

Table 25. Analysis of G X E interaction in eight NPT lines and check variety (Jyothi) in 17 different characters at three locations in Palghat (*Rabi*, 2005)

Genotypes	Panicle length (cm)			Grain yield (t per ha)			Straw yield (t per ha)		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	23.56	-0.02	0.71	5.78	0.42	0.53	6.62	0.59	0.64
NPT-2	21.13	2.66	0.23	7.64	1.86	-0.05	8.46	1.73	0.59
NPT-3	25.46	-0.12	-1.04	7.65	1.65	-0.12	8.49	1.60	0.85
NPT-4	21.82	-2.31	1.41	7.57	0.94	0.88	8.49	1.19	0.73
NPT-5	24.82	0.94	0.35	7.59	1.49	0.63	8.08	1.39	0.54
NPT-6	24.58	1.42	0.52	7.33	1.37	0.45	7.81	1.53	0.07
NPT-7	24.14	4.49	5.82	7.03	1.06	0.63	7.57	1.23	-.11
NPT-8	22.85	2.10	2.07	6.95	0.22	1.59	7.60	-0.16	-.14
Check(Jyothi)	20.48	1.73	1.29	5.65	0.00	0.22	6.49	-0.09	1.18

Genotypes	Harvest index			1000-grain weight (g)		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	0.46	1.13	0.00	24.93	0.71	-0.13
NPT-2	0.47	-0.46	0.00	25.21	0.23	0.02
NPT-3	0.47	0.47	0.00	26.46	-1.04	-0.04
NPT-4	0.47	-0.49	0.0	25.33	1.41	-0.04
NPT-5	0.49	-0.37	0.00	25.52	0.35	-0.07
NPT-6	0.47	1.89	0.0	22.30	0.52	0.05
NPT-7	0.49	-3.01	0.0	27.22	5.82	-0.11
NPT-8	0.48	1.66	0.0	28.94	2.07	-0.08
Check (Jyothi0	0.48	2.26	0.0	27.16	-1.05	0.03

genotypes had recorded zero mean square deviation and regression coefficient near to unity.

4.5.2.10 *Panicle length (cm)*

Among the genotypes, NPT-3 recorded the highest mean value of 25.46 with a regression coefficient of -0.12 and mean square deviation of -1.04.The check variety (Jyothi) recorded lowest mean panicle length (20.48) with a regression coefficient of 1.73 and mean square deviation of 1.29.

4.5.2.11 *1000-grain weight (g)*

Among the genotypes, NPT-8 ranked first with respect to 1000-grain weight (28.94) followed by NPT-7(27.22).The corresponding regression coefficients were 2.07, 5.82 respectively with a mean square deviation of -0.08 and -0.11 respectively.

4.5.2.12 *L/B ratio*

The mean L/B ratio was maximum for NPT-5(3.50) with regression coefficient of 2.93 and mean square deviation of 0.01.Mean L/B ratio was low for NPT-7(2.77) with regression coefficient of -0.77 and zero mean square deviation.

4.5.2.13 *Milling percentage*

The highest mean for this character was observed in NPT-5(77.99) followed by NPT-3(77.68).The corresponding regression coefficients were -0.74 and -1.03 respectively with a mean square deviation of -0.43 and -1.38, respectively. The local check had recorded low mean of 74.89 with a regression coefficient of 1.24 and mean square deviation of 28.59.

Table 25. Analysis of G X E interaction in eight NPT lines and check variety (Jyothi) in 17 different characters at three locations in Palghat (*Rabi*, 2005)

Genotypes	L/B ratio			Milling percentage			Head rice recovery (%)		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	3.50	0.69	0.02	75.50	1.05	0.60	81.10	-0.20	18.93
NPT-2	3.47	0.86	0.08	75.01	1.84	-0.24	82.79	-0.89	-.533
NPT-3	3.40	3.70	0.00	77.68	-1.03	-1.38	84.96	2.99	-5.30
NPT4	3.23	-5.94	0.00	76.80	2.50	2.74	81.54	3.25	7.14
NPT-5	3.57	2.93	0.01	77.99	-0.74	-0.43	79.41	2.97	0.92
NPT-6	3.43	3.79	0.03	77.12	0.79	-0.74	87.30	2.50	4.92
NPT-7	2.77	-0.77	0.00	75.22	2.07	7.96	90.01	0.75	-.500
NPT-8	3.08	-8.37	0.02	76.68	1.28	2.29	89.04	-1.33	-5.34
Check (Jyothi)	3.49	12.13	0.06	74.89	1.24	28.59	81.27	-1.04	-5.21

Genotypes	Kernel elongation ratio			Volume expansion ratio			Amylose content (%)		
	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation	Mean	Regression coefficient	Mean square deviation
NPT-1	1.41	4.21	0.00	4.84	2.02	-0.02	17.17	1.81	-0.05
NPT-2	1.38	2.79	0.00	5.04	-0.49	-0.03	10.62	-4.79	-0.06
NPT-3	1.42	2.41	0.00	5.63	-3.31	-0.02	9.57	0.56	-0.08
NPT-4	1.43	-0.99	0.01	4.55	-5.13	-0.01	16.98	-6.38	-0.07
NPT-5	1.42	0.82	0.00	5.04	2.79	-0.03	10.101	4.17	-0.08
NPT-6	1.37	1.56	0.00	5.22	10.32	-0.01	15.84	1.68	0.08
NPT-7	1.43	5.31	0.00	3.48	5.30	-0.01	13.05	19.78	-0.03
NPT-8	1.46	-3.4	0.00	5.29	-0.06	-0.03	12.24	-1.69	-0.08
Check (Jyothi)	1.48	-3.73	0.00	5.10	-2.46	-0.03	18.84	2.65	-0.08

4.5.2.14 *Head rice recovery*

Among the genotypes, NPT-7 had the highest mean value of 90.01 per cent with regression co efficient of 0.75 and mean square deviation of -0.500.NPT-5 had a low mean value of 79.41 per cent with regression coefficient of 2.97 and mean square deviation of 0.92.

4.5.2.15 *Kernel elongation ratio*

Highest kernel elongation ratio was observed in Jyothi (1.48) with regression coefficient of -3.73 and zero mean square deviation.NPT-6 had the lowest mean value of 1.37 with regression coefficient of 1.56 and zero mean square deviation. All the genotypes had recorded zero mean square deviation.

4.5.2.16 *Volume expansion ratio*

Mean volume expansion ratio was maximum (5.63) with -3.31 regression coefficient and low mean square deviation of -0.02 in case of NPT-3.NPT-7 recorded lowest mean value of 3.48 with regression coefficient of 5.30 and mean square deviation of -0.01.

4.5.2.17 *Amylose content*

Standard check (Jyothi) showed the highest mean value of 18.84 per cent with a regression coefficient of 2.65 and mean square deviation of -0.08.NPT-1 had recorded second best mean of 17.17 with a regression coefficient 1.81 and low mean square deviation of -0.05.NPT-3 had recorded the lowest mean value of 9.57 per cent with regression of 0.56 and mean square deviation of -0.08.

DISCUSSION

5. DISCUSSION

5.1 Mean performance and variability

Rice forms the staple food of Kerala. Currently the state is facing mismatch in its demand and availability of rice, thus depending on neighbouring states for rice supply. High yielding potential of NPT rice lines can be utilized for bridging the gap in demand and availability. To fulfil the objective of testing the suitability and adaptability of these NPT lines under Kerala conditions, the present study was undertaken.

5.1 Mean performance and variability

Eight NPT lines along with a check variety (Jyothi) were tested at three different locations viz., Nenmeni, Thenkurissi and Mathur in Palghat district during *rabi* 2005.Mean performance of NPT lines and check variety were analysed for each character. Better performing NPT lines for each character at each location is discussed below (Plate 1. Morphological characteristics of NPT lines).

At Nenmeni, all the NPT lines and Jyothi had performed uniformly for days to 50 per cent flowering. The average days to 50 per cent flowering in NPT lines was lower (84.95 days) than check variety (89.40 days). It is supported by significantly positive genotypic correlation of days to 50 per cent flowering with grain yield. Kumar *et al.* (1999) reported that days to 50 per cent flowering in NPT lines varied from 80-85 days. In general, NPT lines took 106.43 -116.21 days to maturity whereas check variety (Jyothi) took 118.10 days to maturity. Among the genotypes evaluated, NPT-4 and NPT-5 recorded significantly low mean values (106.43 and 107.21 days respectively) for number of days to maturity whereas Jyothi took more number of days to maturity (118.10) than all NPT lines.

The average plant height for NPT lines was higher (94.37 cm) compared to the check variety (85.20). Even though NPT lines had recorded higher plant height, none of the NPT lines lodged until harvest, indicating their adaptability to mechanical harvest. The average total tillers per plant for NPT lines ranged between 10.82 and 13.30 whereas check variety (Jyothi) produced total tillers of 15.60.This finding is in agreement with earlier report about the number of total tillers per plant in NPT lines (Kumar *et al.*, 1999). In the present study also it was revealed that NPT lines had low number of total tillers, which was similar to that of proposed model plant type in NPT breeding (Peng *et al.*, 1994).

Number of spikelets per panicle was more in NPT lines, the highest being observed for the NPT-2 (200.33) and the lowest for NPT-8 (134.40). The mean number of spikelets per panicle in NPT lines was higher (157.58) when compared to the check variety (122.01).This is in support of the fact that spikelet number of the NPT lines was 11 per cent greater than that of *indica* check varieties (Peng *et al.*, 2004) , One of the objectives of NPT breeding is to enhance the spikelets number to the optimum level.

The mean panicle length for NPT lines was higher (23.82 cm) compared to the check variety (21.18 cm) (Plate 2. Panicle characteristics of NPT lines and root variability). Kumar *et al.* (1999) reported that mean panicle length for NPT lines ranged from 24 cm to 27.3 cm.

The NPT lines, in general showed high average grain yield potential (8.55 t per ha), highest being observed for the NPT-2 (9.62 t per ha) and lowest for NPT-1 (6.62 t per ha). Singh *et al.* (2006) reported that the grain yield ranged from 8.99 to 9.14 for NPT lines, evaluated at CRRI, Orissa, India. In the present study the average grain yield ranged between 6.62 to 9.62 t per ha. More number of spikelets per panicle and more panicle length in NPT lines might have contributed to higher yield in NPT lines. The mean straw yield of NPT lines was also high (9.53 t per ha) compared to the check variety (6.57 t per ha). It was interesting to note that both NPT lines and check variety (Jyothi) did not differ significantly in harvest index.

With respect to the grain quality characters, 1000-grain weight of NPT lines ranged from 22.10 g to 29.10 g with a mean of 25.96 g, which was low when compared to that of check variety (26.75 g). It was worthy to note that NPT- 7 and NPT- 8 had significantly high 1000-grain weight than Jyothi, which is an added advantage to these lines. Peng *et al.* (2004) reported that the 1000-grain weight ranged from 22.2 g to 28.1 g in NPT lines, evaluated at IRRI farm in the wet season of 2003 and the present results are in conformation to this report. The mean L/B ratio for NPT lines was lower (3.28) compared to the check variety (3.87). In general, NPT lines exhibited slender grains, except NPT-7 and NPT-8.

With respect to head rice recovery, NPT-6, NPT-7 and NPT-8 recorded highest head rice recovery (90.00, 90.51 and 89.00 respectively), which was more when compared to that of Jyothi (81.53 per cent). The mean volume expansion ratio was lower in NPT lines (5.20) compared to the check variety (5.45). In general, NPT lines had recorded low amylose content (8-19 per cent), lowest being NPT-3 (9.55 per cent), indicating waxy and stickiness of cooked kernels, which may cause problem in consumer acceptance. The amylose content in Jyothi was 18.74 per cent.

Based on three major economically important characters like number of spikelets per panicle, grain yield and straw yield, NPT-2, NPT-3 and NPT-4 could be ranked as the promising NPT lines at Nenmeni. But the grain qualities of these lines were not promising. On the other hand, NPT 8 showed better grain qualities like medium shaped grains, high 1000-grain weight and better head rice recovery. In general all NPT lines showed low amylose content, which may cause stickiness of grains, thus leading to low consumer acceptance. Comparison for mean performance of these NPT lines along with Jyothi for agronomic characteristics and grain quality characteristics are represented in Fig. 1.

At Thenkurissi, with respect variation in quantitative traits, NPT lines exhibited lower number of days to 50 per cent flowering (86.00 days) when compared to check variety (90.00 days), high mean value for days to maturity (114.85)

NPT-2
(IR 71676 - 90 - 2 -2)

NPT-4
(IR 72176-140-1-2-2)

NPT-5
(IR 73933-8-2-2-3)

NPT-6
(IR 71703-85-7-1-3)

NPT-7
(IR 72158-116-6)

NPT-8
(IR 72158-68-6-3)

Plate.1 Morphologicial characteristics of NPT rice Lines

NPT-3
(IR 73707-45-3-2-3)

NPT-4
(IR 72176-140-1-2-2)

NPT-5
(IR 73933-8-2-2-3)

NPT-7
(IR 72158-116-6)

NPT-8
(IR 72158-68-6-3)

Root Variability

Plate.2 Panicle Characteristics of NPT rice lines

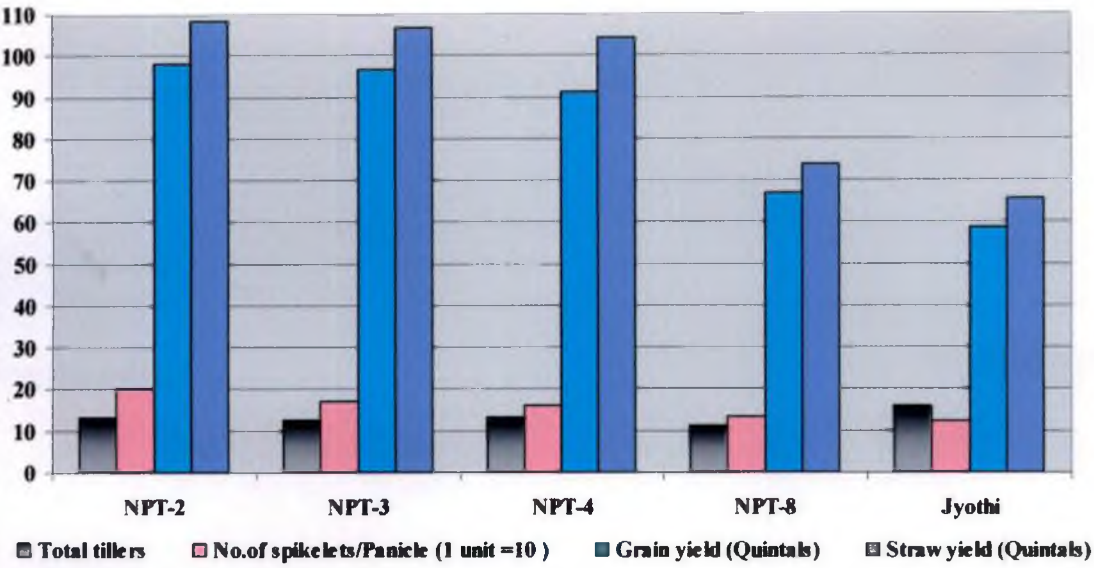


Fig . 1. Mean performence of agronomic characterstic in four superior NPT lines and Jyothi at Nenmeni (*Rabi* , 2005)

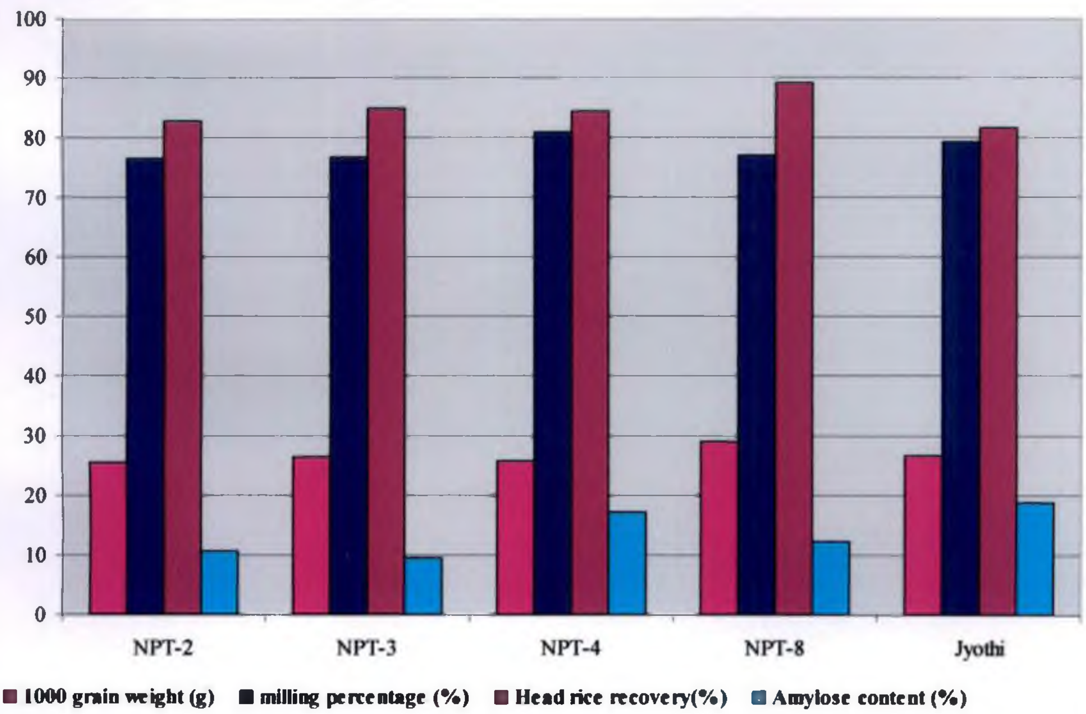


Fig .1. Mean performence of grain quality characterstic in four superior NPT lines and Jyothi at Nenmeni (*Rabi* , 2005)

when compared to check variety (113.61 days), more plant height with a mean of 90.50 cm, more total number of tillers (15.10), higher mean productive tillers (13.79), higher grain yield 7.22 t per ha and higher mean straw yield of 7.50 t per ha.

In general, NPT lines took shorter duration (86.00 days) for days to 50 % flowering as compared to check variety (90.00 days) and 114.85 days to maturity as compared to check variety (113.61 days). High mean grain yield of NPT lines (7.22 t per ha) as compared to check variety (5.18) led to yield advantage of 2.04 t per ha (39.38 per cent over check variety) for NPT lines. Among the NPT lines evaluated, significantly high mean values for grain yield were recorded by NPT-2, NPT-5, NPT-6 and NPT-8 (7.80, 8.25, 7.91 and 8.01 t per ha).Straw yield also followed the same trend. NPT lines had recorded a mean straw yield of 7.50 t per ha while check variety had a mean yield of 5.63. For harvest index, NPT lines and check variety did not differ significantly. As at Nenmeni, here also NPT- 8 had highest 1000-grain weight (28.43 g), with an average of 25.45 g for NPT lines and 27.37 g for check variety (Jyothi).

Lowest L/B ratio was observed for the NPT-7 (2.70) and .except NPT- 7 and NPT- 8 all NPT lines were classified as slender. With regard to milling percentage, NPT-3, NPT-5 and NPT-6 had the highest milling percentage with 79.20, 78.83 and 76.17 respectively. The grain quality traits such as milling percentage, head rice recovery, kernel elongation ratio and volume expansion ratio, NPT lines did not differ much with check variety. On the other hand, amylose content was lower in NPT lines, lowest being observed for the NPT-3 (9.59 per cent). The mean amylose content was much lower in NPT lines (13.22 per cent) than mean of check variety (18.93 per cent), indicating the sticky nature of cooked grains, which may cause problem in consumer acceptance.

Based on major economically important characters like number of spikelets per panicle, grain yield and straw yield, NPT-2, NPT-5, NPT-6 and NPT-8 ranked as the promising NPT lines at Thenkurissi. Comparison for mean performance of these NPT lines along with Jyothi for agronomic characteristics and grain quality characteristics are represented in Fig. 2.

At Mathur, in general, NPT lines exhibited similar trend of variation compared to that of Nenmeni and Thenkurissi for quantitative characters like days to 50 per cent flowering, days to maturity, plant height, grain yield, straw yield and 1000-grain weight.

Days to 50 per cent flowering in NPT lines ranged from 86.67 days to 97.00 days, days to maturity varied from 102.00 to 124.00 days, plant height varied from 85.90 cm to 97.67 cm with a mean value of (90.14 cm). Mean number of total tillers per plant was 15.36, with a mean value of 13.58 for number of productive tillers per plant, 20.28 cm to 25.60 cm long panicles, grain yield ranging from 5.28 to 6.87 t per ha, straw yield ranging between 5.97 to 7.81 t per ha and mean 1000 grain weight ranging from 22.67 g to 29.30 g. With respect to straw yield t per ha, NPT-4 and NPT-8 had the highest straw yield of 7.80 and 7.77 t per ha respectively. It was interesting to note that both NPT lines and check variety did not differ significantly for their harvest index.

With respect to grain quality, the mean L/B ratio of NPT lines was more (3.31), the highest (3.50) being observed for the NPT-1 and NPT- 5 and the lowest for NPT-7 (2.80 which was classified as medium) than check variety (3.17). The mean milling percentage of NPT lines was more (77.40) when compared to the check variety (71.00). In other traits such as head rice recovery, kernel elongation ratio and volume expansion ratio NPT lines did not differ much from check variety. The amylose content in NPT lines ranged between 9.58 to 17.26 per cent, with a mean value of 13.21 per cent when compared to check variety (22.13 per cent). In general, NPT lines had recorded low amylose content (8-18 per cent), indicating waxy and stickiness of cooked rice, even though many other grain characteristics of NPT rice lines were similar to that of Jyothi.Many of the agronomic characters of NPT lines were also same as that of Jyothi (Plate 3.Grain characteristics of NPT lines & Jyothi).

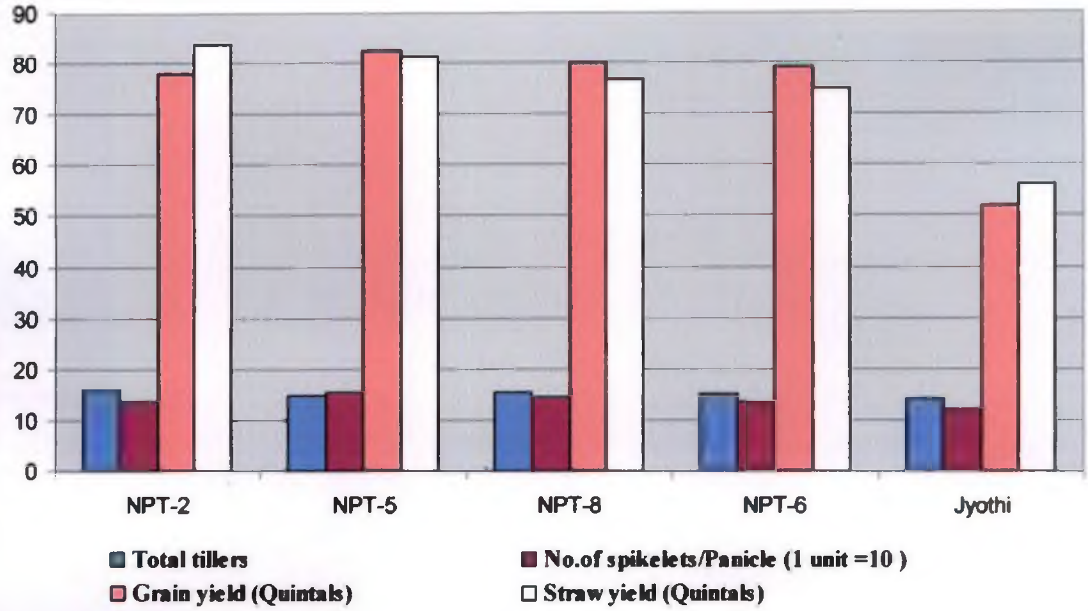


Fig . 2. Mean performence of agronomic characterstic in four superior NPT lines and Jyothi at Thenkurissi (*Rabi*, 2005)

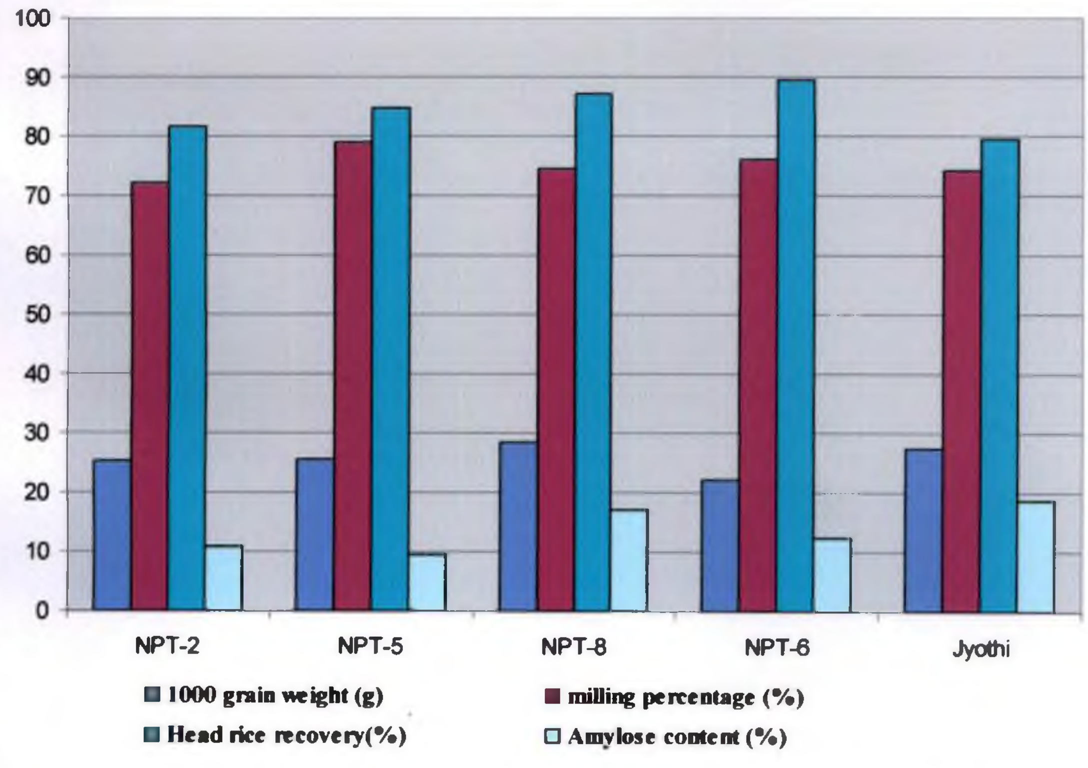


Fig . 2. Mean performence of grain quality characterstics in four superior NPT lines and Jyothi at Thenkurissi (*Rabi*, 2005)

Based on three major economically important characters like number of spikelets per panicle, grain yield and straw yield. NPT-4, NPT-7 and NPT-8 ranked as the promising NPT lines at Mathur. Comparison for mean performance of these NPT lines along with Jyothi for agronomic characteristics and grain quality characteristics are represented in Fig. 3.

5.1.4 Genetic variability

Genetic variability in a crop is the basic requirement for its further genetic improvement. Critical assessment of nature and magnitude of variability is one of the important prerequisites in effective plant breeding. Further, it also aids in the selection of genotypes with desirable traits catering to the need of different agro ecological situations and demands of local markets.

The analysis of variance revealed that genotypes differed significantly for most of the characters at all three locations indicating considerable variation among the genotypes. Number of productive tillers per plant and harvest index did not show significant difference at three locations indicating absence of variability for those characters. Similar trends were found by Sarawagi *et al.* (2000) and Chandrashekhar (2004).

The characters like number of spikelets per panicle, panicle length, grain yield and straw yield , L/B ratio and kernel elongation ratio recorded moderate genotypic coefficient of variation at all the three locations and the characters like number of total tiller per plant, number of productive tillers per plant, number of spikelets per panicle, grain yield and straw yield , L/B ratio, harvest index and volume expansion ratio recorded for moderate phenotypic coefficient of variation at all the 3 locations. Nayak *et al.* (2003), Sinha *et al.* (2004), and Sanalkumar (2005) also found similar results.

Amylose content exhibited higher estimates of phenotypic coefficient of variation in comparison to genotypic coefficient of variation suggesting higher

NPT-1
(IR 73971-87-1-1-1-1)

NPT-2
(IR 71676 - 90 - 2 -2)

NPT-3
(IR 73707-45-3-2-3)

NPT-4
(IR 72176-140-1-2-2)

NPT-5
(IR 73933-8-2-2-3)

NPT-6
(IR 71703-85-7-1-3)

NPT-7
(IR 72158-116-6)

NPT-8
(IR 72158-68-6-3)

Jyothi

Plate.3 Grain characteristics of NPT rice lines & Jyothi

influence of environment on the trait. Similar results were also found by Yadav *et al.* (2002).

5.2 Heritability, genetic advance and genetic gain

The degree of genetic variability and the magnitude of heritability of desirable characters decide the success of a crop improvement programme. The pre-requisites for any breeding programme are the information on the estimates of variability and heritable components with respect to yield and grain quality in a breeding material. Hence, it becomes essential to split the variability components with the help of genetic parameters such as heritability, genetic advance and genetic gain. The results obtained in the present study are discussed below.

The characters namely days to 50 % flowering, days to maturity, panicle length, grain yield, straw yield, 1000 grain weight, L/B ratio, head rice recovery, kernel elongation ratio, volume expansion ratio and amylose content exhibited high degree of heritability (broad sense). Thus, it can be inferred that these traits are less influenced by environment, but selection for improvement of these characters may not be useful, because broad sense heritability is based on total genetic variance which include both fixable (additive) and non fixable (dominance and epistatic). The result is in accordance with the findings of Reddy (2000). Similar reports were also made by Nayak *et al.* (2002) for grain yield and Mahto *et al.* (2003) for days to 50 % flowering and 1000- grain weight, Chaudhary and Motiramani (2003) for all characters except harvest index.

The heritability estimates can be used for the selection of a genotype based on phenotypic performances (Johnson *et al.*, 1955). Therefore, high heritability does not necessarily mean greater genetic gain. Hence, genetic gain was calculated in order to ascertain its relative utility.

High estimates of genetic gain coupled high heritability recorded for grain yield and straw yield at Nenmeni and Thenkurissi, as well as for amylose content at

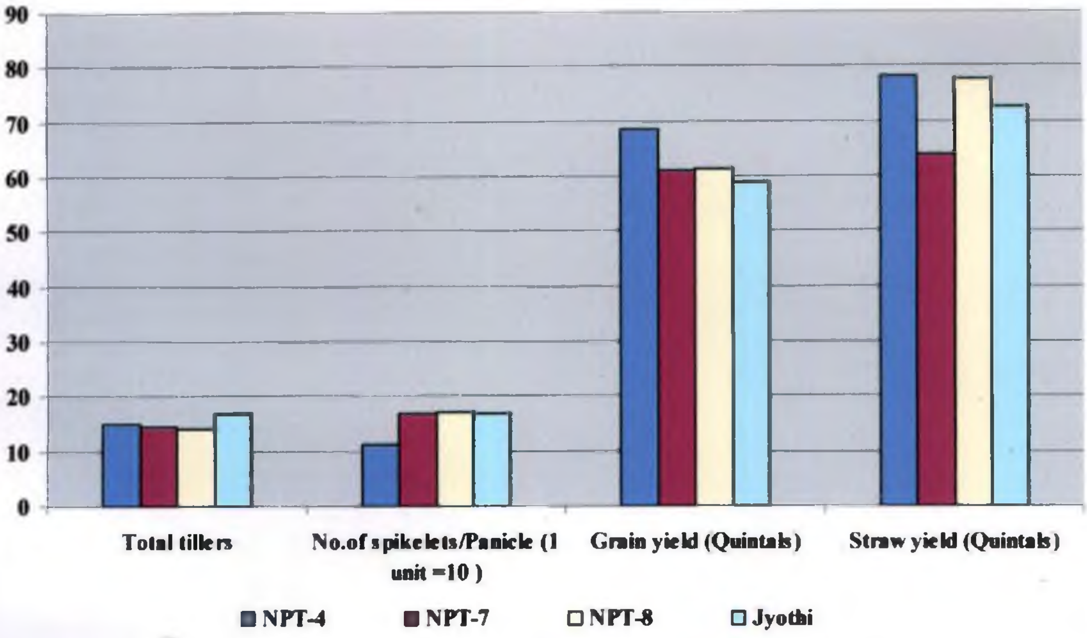


Fig .3. Mean performence of agronomic charactersitics in three superior NPT lines and Jyothi at Mathur (Rabi, 2005)

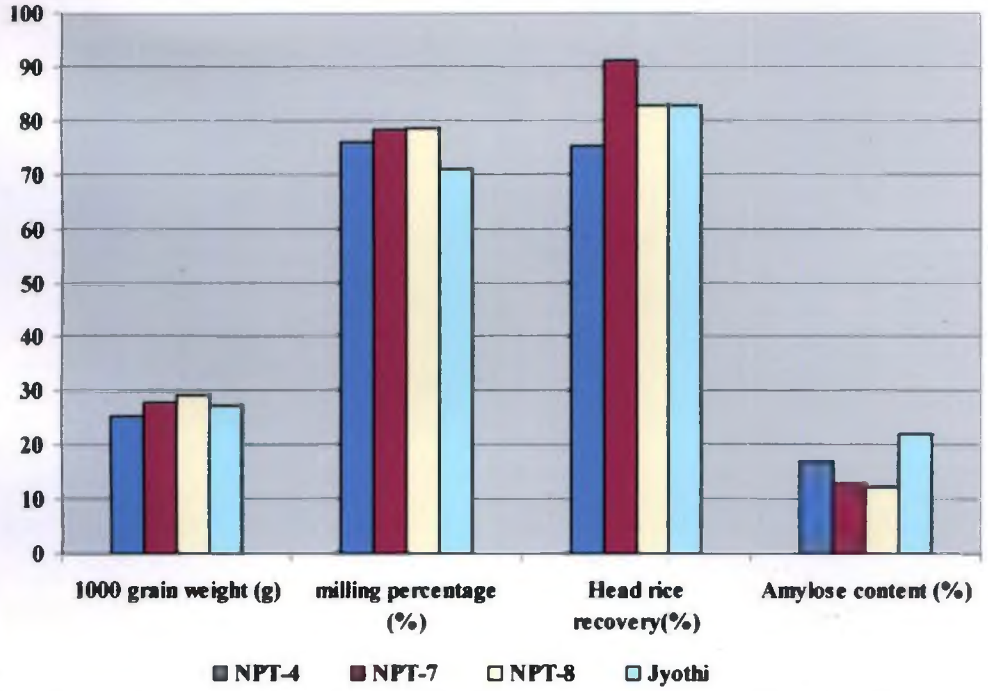


Fig .3. Mean performence of grain quality charactersitics in three superior NPT lines and Jyothi at Mathur (*Rabi* , 2005) all locations, indicated additive gene action. Thus, it can be inferred that above characters with high genetic gain and high heritability are governed by additive genes and selection will be rewarding for improvement of such traits. Similar results are also made by Sanalkumar (2005) for grain yield and straw yield. Majority of characters exhibited high heritability coupled with low genetic advance, indicating non-additive gene action. Selection for such traits will not be rewarding as the high heritability is exhibited due to favorable influence of environments.

5.3 Correlations

In plant breeding the study of association of characters is of utmost importance as they aid plant breeders to know the inter character influence which in turn helps to pin point economic and reliable balance among various characters. Grain yield is a complex character and hence any practice of single character selection often results in less progress in the genotypes. Therefore, knowledge of inter relation ships of characters plays a pivotal role in developing suitable selection criteria for the improvement of complex characters like grain yield. The results of correlation studies between grain yield and yield characters in NPT lines are given below.

In the present study, it was revealed that yield was positively correlated with days to 50 % flowering, number of spikelets per panicle, panicle length and straw yield indicating the importance of these traits in direct selection. Sao *et al.* (2004), Satyanarayana *et al.* (2005) and Souroush *et al.* (2004) also observed significant positive correlation of grain yield with days to 50 per cent flowering and number of spikelets per panicle.

Sao *et al.* (2004) also reported significant positive genotypic correlation of grain yield with panicle length. Manuel and Palanisamy (1989) and Satya (1999) reported significant positive genotypic correlation between grain yield and days to 50 per cent flowering. Surek and Besar (2003) reported significant positive genotypic correlation between grain yield and straw yield.

Performance of NPT lines genotypes in three locations revealed similar trend. Grain yield was positively correlated with days to 50 per cent flowering, number of spikelets per panicle, panicle length and straw yield, indicating that the association between grain yield and these characters is high.

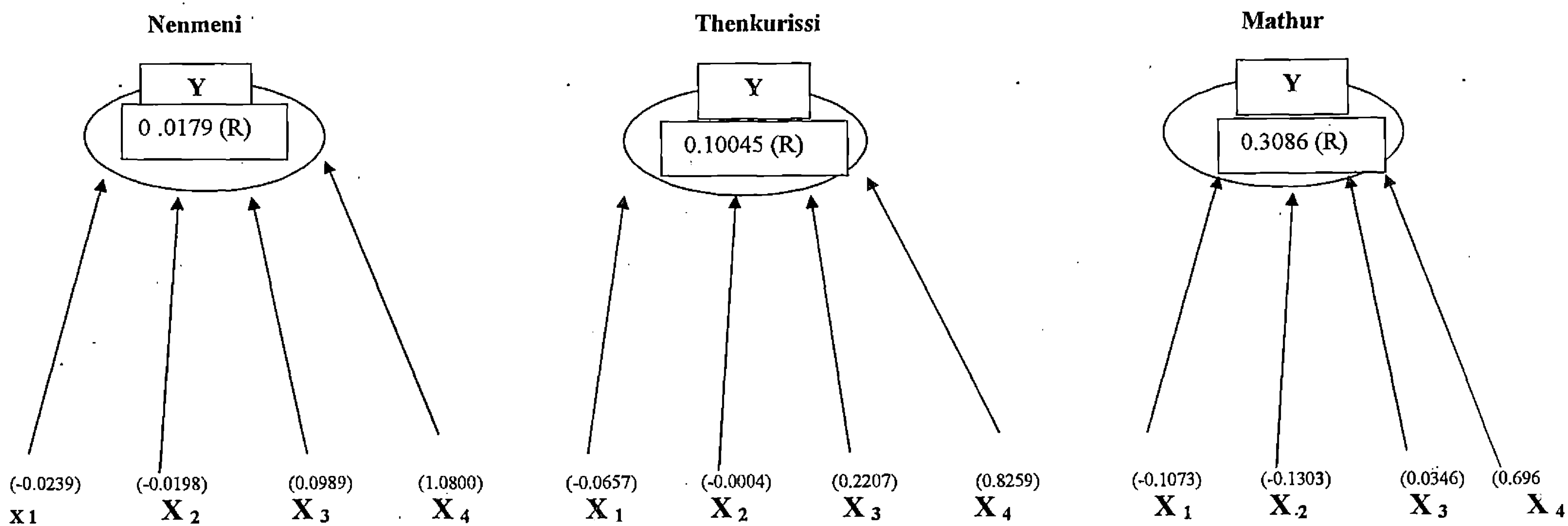
5.4 Path analysis

Path coefficient analysis is a standardized partial regression coefficient, which splits correlation coefficient into measures of direct and indirect effects. It measures the direct and indirect contribution of characters on dependent characters. Even though correlation study is helpful in measuring the association of yield and yield components, it do not provide clear picture of the direct and indirect effects of associations, but through path analysis that can be obtained. Path analysis at each location is represented in Fig.4 for Nenmeni, Thenkurissi and Mathur.

Path analysis in the present study revealed that in all three locations the highest direct effect was exhibited by straw yield, which was in concurrence with the report by Reddy (2000). Plant height and number of total tillers per plant exhibited negative direct effect on grain yield and this in justification about the character selection in NPT breeding programme. If these traits are increased beyond a limit, it will lead to a yield reduction in NPT lines. Characters like days to maturity, number of spikelets per panicle, straw yield and 1000-grain weight showed positive direct effect on grain yield. Hence in breeding programme for further improvement of NPT lines these characters are to be given due emphasis. Shanthala *et al.* (2004) reported that plant height and number of total tillers per plant had negative direct effect on grain yield. Days to maturity and number of spikelets per panicle had the positive direct effect on grain yield as reported by Vaithiyalingam and Nadarajan (2005).

The residual effect obtained in path analysis for three locations ranged between 0.0179 and 0.3086 indicating that most variation in grain yield was contributed genotypically by these selected yield components.

Fig. 4. Path diagram indicating direct effect of yield attributing characters on grain yield at Nenmeni, Thenkurissi and Mathur respectively.



Y- Grain yield

R- Residual effect

X_1 - Plant height

X_2 - Number of total tillers per plant

X_3 - Number of spikelets per panicle

X_4 - Straw yield

5.5 Genotype x Environment (G x E) interaction

Crop breeding presently aims at developing varieties with high yield potential coupled with wide adaptability. Hence, G x E interaction structure is important for both plant-breeding programmes and in the introduction of new cultivars. The genetic character of this wide adaptability is mainly comprised of two component characters, i.e. stability and productivity (Mahapatra and Das, 1999). The relative value of adaptability is determined by the degree of stability and that of productivity (yielding ability) of respective varieties under various environments. Reaction of genotypes to environmental variables during the crop period exerts considerable influence on the expression of their yield potential. The yield of many of the high yielding rice varieties remain far below their potential yield during different seasons (Elsy *et al.*, 1995).

The performance of genotypes for each character in response to environment are discussed adopting the model of Eberhart and Russel (1966). Analysis of G x E interaction of characters in eight NPT rice lines and check variety (Jyothi) is presented below.

5.5.1 Days to 50 % flowering

Among the NPT rice lines tested, NPT-7 followed by NPT-8 with regression coefficient near unity, high mean value and low mean square deviation can be considered as most stable for this character over the locations.

5.5.2 Days to maturity

Among the NPT lines, NPT-7 followed by NPT-8 having regression coefficient near to unity and low mean square deviation found to be more stable in different locations.

5.5.3 Plant height

Stability parameters had identified that NPT- 1 with regression coefficient near to unity and low mean square deviation can be considered as more stable for this trait. The check variety (Jyothi) showed to be specially adapted to less favorable environments of NPT lines.

5.5.4 Number of total tillers per plant

Stability parameters of high mean value, regression coefficient near to unity and mean square deviation near to zero for NPT-5 indicated its stability for this character.

5.5.5 Number of productive tillers per plant

Stability parameters had identified that check variety (Jyothi) having high mean value and regression coefficient below unity with low mean square deviation indicating its suitability under less favorable conditions compared to favorable conditions for NPT . NPT-1 with low mean value, regression coefficient below unity and low mean square deviation was found to be more stable under varied environments whereas NPT-3 with regression coefficient more than one may be suitable for conducive environments.

5.5.6 Number of spikelets per panicle

NPT 1 with mean number of spikelets of 144.37 and regression coefficient less than one and comparatively low mean square deviation was found to have relatively better stability for this character.

5.5.7 Panicle length

NPT-5 had exhibited high mean value, mean square deviation near zero and regression coefficient near to unity and was found to be stable over the locations while check variety (Jyothi) with low mean value and regression coefficient above unity was found to be specially adapted for favorable environments for this character.

5.5.8 Grain yield

NPT-4 followed by NPT-7 had exhibited high mean value, low mean square deviation and regression coefficient near to unity indicating stability over environments.

5.5.9 Straw yield

Stability parameters had identified that NPT- 4 followed by NPT- 7 with high mean value, regression coefficient near to unity and low mean square deviation are stable genotypes for this character.

5.5.10 Harvest index

NPT-1 was found most stable for this character having high mean value, regression coefficient below to unity and zero mean square deviation.

5.5.11 1000- grain weight

NPT- 4 exhibited high mean value, mean square deviation near zero and regression coefficient above unity signifying its stability. NPT- 8 and NPT- 7 with high mean value, low mean square deviation and regression coefficient above unity revealing its special adaptation to certain specific environments.

5.5.12 L/B ratio

NPT-2 with high mean value and regression coefficient near to unity and low mean square deviation was identified as comparatively stable.

5.5.13 Milling percentage

Stability parameters had identified that NPT-1 high mean value, low mean square deviation and regression coefficient near unity found stable and widely adapted to different environments.

5.5.14 Head rice recovery

NPT-7 with high mean value, regression coefficient near to unity and low mean square deviation found to be specially adapted for varied environments.

5.5.15 Kernel elongation ratio

NPT 5 with high mean value, regression coefficient near to unity and low mean square deviation found stable for this trait to all environments.

5.5.16 Volume expansion ratio

All the NPT lines showed inconsistant performance to this character.

5.5.17 Amylose content

Stability parameters had indicated that inconsistant performance as in the case of volume expansion ratio

Genotype x environment showed that NPT 1 was stable for plant height, number of spikelets per panicle, harvest index and milling percentage.NPT 2 was the stable line for L/B ratio. NPT 4 was the stable line for grain yield, straw yield and 1000-grain weight. NPT 5 was stable for number of total tillers per plant, panicle length and kernel elongation ratio. The performance of NPT 7 was stable for days to 50 per cent flowering, days to maturity, grain yield, straw yield, harvest index and head rice recovery whereas NPT 8 was the stable line for days to 50 per cent flowering.Jyothi was stable for number of productive tillers per plant.

All the above results revealed that NPT lines, NPT 1, NPT 4 and NPT 7 had done well with respect most of quantitative characters such as days to 50 per cent flowering, days to maturity, number of spikelets per panicle ,grain yield ,straw yield, harvest index, milling percentage and head rice recovery. But most of NPT lines faired poor with respect to grain qualities suggesting superiority of Jyothi (Check variety) for these traits. Hence, to understand the potential of NPT lines there is signal to improve qualities characters. Similar suggestions were given by Khush and Virk (2004) and Virk *et al.* (2004).

Future line of work

1.Though in general NPT lines was on par or better than check variety for yield and yield related characters, their grain quality characters were poor. This can reduce their marketability and further spread. Hence efforts must be directed to evolve NPT lines with better grain quality and sustained grain yield.

2.Considering the preference of Kerala people for red bold rice, efforts must be strengthened to evolve better NPT lines having red kernel colour.Identification of elite parents having red bold grains and using them in back cross breeding programme may help to evolve such NPT lines.

SUMMARY

6. SUMMARY

A study was carried out in the Department of Plant Breeding & Genetics, College of Horticulture, Vellanikkara during *rabi* 2005 to evaluate the genotype - environment interaction in NPT rice lines (developed at IRRI) in the central zone of Kerala.

Eight selected NPT rice lines along with Jyothi as check variety were analysed for mean performance, variability, correlation, path analysis and stability at three locations viz., Nenmeni,Thenkurissi and Mathur during *rabi* (dry season) of 2005. The results are summarized below.

1. In general days to 50 per cent flowering in NPT rice lines did not differ from that of Jyothi at all the test locations. Days to maturity in NPT lines ranged between 106.33 to 119.67 days whereas Jyothi took 117.33 days to maturity.

2. The average plant height of NPT lines was same or higher than that of Jyothi. None of the lines showed tendency to lodge.

3. NPT lines and Jyothi produced same number of productive tillers ranging between 12.18 to 13.28 at all the locations.

4. In general panicle length was more in NPT lines; Mean number of spikelets per panicle was also high in most of NPT lines than Jyothi.

5. At Thenkurissi and Nenmeni majority of NPT lines exhibited a higher grain yield potential than Jyothi. NPT lines expressed 45 per cent and 39.38 per cent higher grain yield than Jyothi at Thenkurissi and Nenmeni respectively. At Mathur, performance of NPT rice lines for grain yield potential was same as that of Jyothi.

6. It was interesting to note that harvest index was same in NPT rice lines and Jyothi at all locations.

7. Most of the grain characteristics of NPT rice lines were comparable with Jyothi except for amylose content. Low amylose content of NPT lines indicated stickiness of grains, which may cause problem in consumer acceptance in Kerala.

8. Based on the economical importance and agronomic characters, promising NPT rice lines for each location were identified. At Nenemni, the promising NPT lines identified were NPT-2, NPT-3 and NPT-4.Taking into consideration of grain quality parameters like medium shaped grains, high 1000-grain weight and head rice recovery, NPT-8 was adjudged as the best NPT line at Nenmeni. NPT-2, NPT-5, NPT-6 and NPT-8 were identified as the promising four NPT rice lines at Thenkurissi. At Mathur, NPT-4, NPT-7 and NPT-8 were identified as the promising NPT rice lines.

9. Among NPT lines, NPT-8 had shown better grain qualities except amylose content. This line had recorded a L/B ratio of 2.88, 1000- grain weight of 28.94 g, milling percentage of 76.68 and head rice recovery of 89.04.The mean amylose content was 12.24 per cent compared to 18.84 per cent in Jyothi.

10. The analysis of variance revealed considerable variability for most of the characters among the genotypes at three locations in central zone of Kerala.

11. High heritability with high genetic gain was observed for characters like grain yield, straw yield and amylose content at Nenmeni and Thenkurissi.Selection will be rewarding for the improvement of such characters. Majority of characters exhibited high heritability coupled with low genetic advance at all the locations tested. Selection may not be useful for such characters.

12. Days to 50 per cent flowering, number of spikelets per panicle, panicle length and straw yield exhibited positive correlation with grain yield in NPT lines.

13. Path analysis in the present study revealed that, the characters like days to maturity, number of spikelets per panicle, straw yield and 1000-grain weight had significant positive direct effect on grain yield .Straw yield exerted high positive effect on grain yield in most of the characters studied.

14. Stability parameters identified that NPT- 1 was stable for plant height, number of spikelets per panicle, harvest index and milling percentage.NPT- 2 was the stable line for L/B ratio. NPT- 4 was the stable line for grain yield, straw yield and 1000-grain weight. NPT- 5 was stable for number of total tillers per plant, panicle length and kernel elongation ratio. The performance of NPT- 7 was stable for maximum number of characters viz., days to 50 per cent flowering, days to maturity, grain yield, straw yield, harvest index and head rice recovery. NPT -8 was the stable line for days to 50 per cent flowering whereas Jyothi was stable for number of productive tillers per plant.

15. Based on the performance for yield, agronomic characters, grain characteristics and stability NPT-7 had shown better performance in the present study. This line has 89.11 days to 50 per cent flowering, 119.67 days to maturity ,90.26 cm of plant height,13.74 total tillers per plant,12.80 productive tillers per plant,145.72 spikelets per panicle,24.14 cm of panicle length,7.03 t per ha of grain yield and 7.57 t per ha of straw yield and grain quality characters like a L/B ratio of 2.77 (medium sized grains), milling percentage of 75.22, head rice recovery of 90.01 per cent , kernel elongation ratio of 1.43, volume expansion ratio of 3.48 and amylose content of 13.05 per cent.

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GENOTYPE - ENVIRONMENT INTERACTION IN NEW PLANT TYPE (NPT) LINES OF RICE (*Oryza sativa* L.)

By

M. MARIMUTHU

ABSTRACT OF THE THESIS

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Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Plant Breeding & Genetics

COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

The present study on Genotype - Environment interaction in New Plant Type (NPT) lines of rice was carried out in the Department of Plant Breeding & Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara.

Eight selected NPT rice lines (developed at IRRI) along with Jyothi as check variety were evaluated for ten agronomic characteristics and seven grain quality characteristics across three low land rice ecosystem in Palghat district in central zone of Kerala during *rabi* season 2005. In the experiment, variability, heritability, genetic advance, correlation, path analysis and stability were disclosed.

Mean performance of NPT rice lines across three locations revealed that in general NPT rice lines performed significantly better than check variety at two locations for grain yield. Characters like days to 50 per cent flowering and number of productive tillers and harvest index did not differ significantly than that of Jyothi at all the test locations. With respect to grain quality parameters such as L/B ratio, 1000-grain weight, milling percentage and head rice recovery. NPT-8 had shown better grain qualities except amylose content.Jyothi showed superior performance for this character. In general, panicle length and mean number of spikelets were high in most of NPT rice lines than Jyothi.The average plant height of NPT lines was same or higher than that of Jyothi.None of the NPT rice lines showed tendency to lodge. Grain yield was positively and significantly correlated with days to 50 per cent flowering, number of spikelets per panicle, panicle length and straw yield .Path analysis indicated that characters like days to maturity, number of spikelets per panicle, straw yield and 1000-grain weight had the positive direct effect on grain yield.

Based on the economical important agronomic characters, promising NPT rice lines for each location were identified. At Nenemni, the promising NPT lines identified were NPT-2, NPT-3 and NPT-4.Taking into consideration of grain quality parameters like medium shaped grains, high 1000-grain weight and head rice recovery, NPT-8 was

adjudged as a best NPT line at Nenmeni.NPT-2, NPT-5, NPT6 and NPT-8 were identified as the promising four NPT rice lines at Thenkurissi. At Mathur, NPT-4, NPT-7 and NPT-8 were identified as the promising NPT rice lines. Based on the performance for yield, agronomic characters, grain characteristics and stability NPT-7 had shown better performance in the present study.

Appendix – I Climatological details of Palghat district (*Rabi,* 2005).

Particulars	Palghat Dst.
Mean Sea Level (m)	40 m above MSL
Mean Rainfall (mm)	2403
Maximum temperature (^{0}C)	36 ± 0.32
Minimum temperature(^{0}C)	17 ± 0.64
Relative humidity (%)	67.69 – 88.21