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Society for Advancement of Rice Research

Society For Advancement of Rice Research

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The Society for Advancement of Rice Research is a registered society for researchers, research managers extension personnel, institutions, development agencies, trade and industry who practice and promote activities for the advancement of rice science and development. The society has been started with overall objectives of providing a platform for exchange information and knowledge and disseminate the latest developments in rice research and to bring together all persons / institutions working for the cause of rice.

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- To advance the cause of rice research and development in the country.
- To disseminate knowledge on latest development in rice research through publications, seminars, lectures and training programs.
- To provide a platform for exchange of knowledge and information on rice research and developments through organizing workshops, symposia, conferences, etc.,
- To provide consultancy in rice production and development.
- To facilitate research and Industry collaboration and public private partnership at national level.
- To honour outstanding achievers in rice research and development.
- To cooperate with other organizations having similar aims and objectives
- To promote any other scientific/professional activities conducive for the advancement of science of rice and rice improvement.

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CONTENTS

Invited Article

Biopesticides for Insect Pest Management in Rice – Present Status and Future Scope

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Insect pests – major biotic stresses in rice

Of the hundred and more species of insects recorded as pests in rice, five pests *viz.*, rice yellow stem borer (YSB), *Scirpophaga incertulas* (Walker), gall midge (GM), *Orseolia oryzae* (Wood-Mason), leaf folder (LF), *Cnaphalocrocis medinalis* (Guenee), brown plant hopper (BPH), *Nilaparvata lugens* (Stal) and white backed plant hopper (WBPH), *Sogatella furcifera* (Horvath), are of national importance as their incidence has significant impact on rice yields across the diverse rice ecosystems. Other pests *viz.*, rice hispa, *Dicladispa armigera* (Olivier) occurring in Andhra Pradesh, Himachal Pradesh, Bihar, West Bengal, Orissa and north eastern region, green leafhopper, (GLH) *Nephotettix virescens* (Distant) prevalent in Bihar, West Bengal, Assam, Orissa, Madhya Pradesh, Andhra Pradesh and Tamil Nadu, gundhi bug, *Leptocorisa* spp. in Uttar Pradesh, Bihar, West Bengal, Orissa, Madhya Pradesh, Manipur and parts of Andhra Pradesh, climbing cutworm, *Mythimna separata* (Walker) in coastal upland rice growing areas, swarming caterpillar, *Spodoptera mauritia* (Boisduval) in low lying rice in Bihar, Gujarat, West Bengal, Assam and Orissa and thrips in several southern and eastern parts of India, have regional significance. Some pests such as rice mealy bug, termites, and case worm are pests of growing concern particularly in eastern region. Recently, leaf and panicle mites, black bugs, blue beetle have also started causing serious concern as emerging pests in some parts of the country.

Biointensive management of insect pests –a potentially viable long term alternative

Biointensive approach of managing pests is an ecologically based strategy that focuses on long term solution for pest control through a combination of techniques such as use of resistant varieties, biological control, modification of agronomic practices and habitat manipulation. Use of biopesticides mainly, microbial insecticides and botanical products will have to be an integral component of such an approach to minimize the risks to the human health, beneficial and non target organisms and environment.

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Natural regulation of insect pests in rice ecosystem by entomopathogens

Paddy ecosystems are richly endowed with natural regulatory mechanisms to take care of the insect pests and entomopathogens are one of the major groups among the natural enemies. Of the eleven insect pathogens reported to attack stem borer, *Bacillus thuringiensis* is the major one. Against leaf folder, eighteen fungal, two bacterial, two viral pathogens and two entomopathogenic nematodes have been reported. Among the entomopathogens reported on plant and leafhoppers, the fungi, *Pandora delphacis*, *Metarrhizium flavoviridae*, *Beauveria bassiana*, *Erynia radicans*, *Entomophthora*, *Entomophaga aulicae* and *Fusarium* sp. have shown promise. Though the natural action of entomopathogens against the pests has been well documented and reported their inherent ability to naturally regulate the pest populations below the economically damaging levels, has not been evident.

Efficacy of plant products against rice pests

Four major types of botanical products (pyrethrum, rotenone, neem and essential oils) have been widely used for insect pest management along with three others (ryania, nicotine and Sabadilla) in limited scale. Additional plant extracts and oils (eg. Garlic oil, *Capsicum* oleoresin etc.) have also been or being used in a limited way, specific to regions (Anand Prakash *et al.,* 2008). However, neem and its products with more potential have been better investigated than other products. Two types of crude botanical products can be obtained from the neem seeds. Neem oil, obtained by cold pressing of seeds and seed residue (cake) after removal of oil, which contains the major active principle, Azadirachtin. Neem seeds also contain 0.2 to 0.6% azadirachtin by weight and this active ingredient is concentrated to the level of 10 to 50% in the technical grade material used to produce commercial products. Neem oil and neem cake have been extensively tested for their efficacy against various pests of rice. There are several reports on their utilization in rice pest management (Table 1). However, their performance has been moderate and also inconsistent in comparison to chemical insecticides which have also been found superior in terms of their curative effect, easy application and availability.

Biopesticides – as key components of integrated pest management

Pest control methods have been evolving and diversifying in response to public awareness of environmental and health impacts of synthetic pesticides and resulting legislation. In this process, standardization of active principles of botanical products and their contents was done by suitably formulating them as biopesticides for reliable, better and consistent results. Biopesticides were also developed as key components of integrated pest management (IPM) programs, mainly as a means to reduce the load of synthetic chemical products that are being used for control of pests. The biopesticides used so far fall into two major categories *viz.*, microbial pesticides and botanical pesticides (Ranga Rao *et al.*, 2007).

Microbial insecticides

Microbial pesticides contain a microorganism (bacterium, fungus, virus, protozoan or alga) as the active ingredient which is relatively specific for its target pest(s). The most widely known microbial pesticides are derivatives of the bacterium *Bacillus thuringiensis* (Bt) which produces a toxin protein that is harmful mainly to lepidopterans. In the last decade, Bt transgenics have been developed which are considered equivalent to plant-pesticides where in the Bt toxin gene introduced into the plants own genetic material results in the plant itself manufacturing the toxin that kills the pest.

Evaluation of Bt formulations in rice

Several commercial formulations of Bt have been evaluated for their effectiveness against mainly leaf folder and stem borer in rice. Under the All India Coordinated Rice Improvement Programme (AICRIP), three commercially available formulations *viz.*, Delfin 85%, Dipel 3.5% and BTK II were evaluated focusing on their efficacy against leaf folder besides their concomitant effectiveness against stem borer was also investigated. It was evident that all the three formulations performed moderately against leaf folder, while the effect was marginal in case of stem borer, across ecosystems. The Bt formulations registered better effectiveness at higher doses, however the check insecticide chlorpyriphos showed consistent superiority both in terms of less pest incidence as well as higher yield.

Rath (1999) found that BTK II and Dipel 3.5% were more effective than Delfin 85% and Biolep. Roshan Lal (2001) observed that Bioasp, Biolep, Biotox, dipel and Delfin @ 2000 g a.i./ha were as effective as standard chlorpyriphos @ 250 g a.i./ha against leaf folder. Recent studies carried out on bio-efficacy of an indigenously developed Bt formulation (DOR Bt) at various concentrations by Directorate of Oil seeds Research (Ramandeep Kaur *et al.*, 2008; DRR, 2007-08) revealed that the formulation @ 2.0 kg/ha was effective in controlling the rice leaf folder (Fig 1) and increasing the grain yield of rice.

Evaluation of Bt formulations in combination with other components of IPM

Research efforts have also been aimed at evaluation of Bt formulations as one of the eco-friendly components of IPM modules for adoption across rice ecosystems along with other components such as botanical insecticides, insect growth regulators, biocontrol agents, conventional chemical insecticides as well.

Rao *et al.* (2003) reported that alternating the application of insecticides with Biobit or Dispel sprays were more effective than sole biopesticidal treatments in controlling leaf folder and increasing rice grain yield over control. The combination of biobit with systemic insecticides was also found to be economical as well as eco-friendly as it resulted in the best control of the pest and also conserved the natural enemies such as coccinellids and spiders in the rice field (Rao and Singh, 2003; Rao *et al.,* 2006). In another study, CAMB Bt (*Bacillus thuringiensis*) at 250 g/acre and CAMB fungi (*Metarrhizium anisopliae*) at 250 g/acre applied alone or in combination resulted in significant reduction in leaf folder and stem borer incidence (Shahid *et al* ., 2003).

Overall, the utility of Bt formulations in paddy ecosystems has been mainly limited by the inability of externally applied sprays to actually reach the target pest stages which are mostly hidden in case of stem borer which completes most of its life cycle within the plant system, while in case of leaf folder, the larvae feed remaining within the leaf folds thereby escaping exposure from direct spray. So, the timing of application is crucial for the effectiveness of Bt formulations. However, in recent times, the versatile biotechnology tool has provided a novel option of incorporating Bt genes like *cry IA (b)* and *cry IA (c)* which can trigger continuous production of insecticidal toxins in the plant system itself to overcome this problem. Already Bt transgenic rice varieties for resistance to yellow stem borer are in advanced stage of testing in India ((Manimaran *et al.*, 2011).

Studies on efficacy of other microbial insecticides in rice

In India, so far, eight microbial pesticides have been registered which include five of bacterial origin (four *Bacillus* species and one *Pseudomonas fluorescens*), three fungal origin (two *Trichoderma* species and one *Beauveria bassiana*) and one viral i.e. Nuclear Polyhedrosis Virus (NPV). In India, there are very few reports on evaluation of other microbial insecticides in rice, that too restricted to *Beauveria bassiana* based products, against leaf folder but without much success (Rao *et al.*, 2003; Sher Singh *et al.,* 2008).

Botanical insecticides

Botanical insecticides are synthetic derivatives of the naturally occurring secondary metabolites synthesised by plants species, which act on the insect growth and survival. They have long been advertised as attractive substitutes to synthetic chemical-insecticides, for controlling many insect pests because botanicals reputedly pose little threat to the environment or to the human health. Although, there is enormous scientific literature documenting bioactivity of plant derivatives to arthropod pests yet only pyrethrum and neem are well established commercially (Isman, 2006). In India, a wide variety of commercial neem formulations have been tested and sold and newer ones continue being marketed by local formulators.

Evaluation of efficacy of neem formulations in rice

Wide ranging greenhouse and field studies were carried out at the Directorate of Rice Research (DRR), Hyderabad to evaluate the efficacy of ready to use neem formulations against the insect pests of rice (Krishnaiah *et al.,* 2008). Evaluation studies were carried out on two types of neem formulations *viz.,* i) Oil based formulations with 300 ppm of azadirachtin and ii) Solvent based formulations with 1500 ppm or more of azadirachtin. The studies focused on antifeedant, growth regulating, development-modifying and insecticidal effects.

Under glasshouse conditions, studies on feeding deterrent effects revealed that Rakshak and Neemgold 4 were superior to Neem Azal T/S in case of BPH and leaf folder. Mayabini Jena (2005) also reported that antifeedant and oviposition deterrent activities were more prominent than the knock down effects. In case of leaf hoppers and plant hoppers, disruption of growth resulted in reduction in size and weight of insects after feeding on plants treated with crude or commercial neem formulations. Consequently the proportion of nymphs becoming adults was also affected. However, in lepidopterous insects larval pupal intermediaries were observed (Krishnaiah and Kalode, 1988). Although there are reports that oviposition by BPH, WBPH and GLH are affected when confined to plants treated with neem oil or neem formulations, there was no consistency in such effects (Kalode and Krishnaiah, 1991). Further, studies with neem formulations (Krishnaiah *et al.,* 2000) revealed that the oil based neem formulations were more effective in oviposition deterrency than solvent based neem formulations as sprays. The studies have revealed that constituents other than Azadirachtin also play a role in exercising toxic effect against BPH. Some neem formulations with high azadirachtin content like Neem Azal T/S have exhibited some systemic activity when given as a seedling root dip adversely affecting the growth and development of BPH and GLH nymphs when confined to treated plants (Krishnaiah *et al.,* 2000). Neem formulations as spray also adversely affected the survival of BPH through toxic effects. Saikia and Parameswaran (2001) also reported more than fifty per cent mortality of leaf folder larvae after direct exposure to neem azal –F 5% treatment.

The extensive research on the field efficacy of neem products has included evaluation of several neem based formulations for the control of brown plant hopper, yellow stem borer and leaf folder. Field experiments at DRR as well as multi- location trials under the All India Coordinated Rice Improvement Programme (DRR, 1995-97) revealed that neem formulations *viz.,* Achook, Nimbecidine, Neemax, Neemgold and Econeem at recommended concentrations (2% in oil based formulation) were moderately effective against stem borer (6.5 to 7.1% dead hearts-DH and 10.2 to 11.6% white ears-WE) and leaf folder (17.0 to 26.0 average damaged leaves - ADL per 10 hills) compared to standard insecticide check (5.4% DH, 8.0% WE and 19.2% ADL) but were significantly superior to control (11.3% DH, 14.8% WE and 42.4% ADL). The neem formulations were not effective against rice gall midge. It is also evident from other studies that the neem formulations effectively controlled BPH and WBPH, moderately suppressed stem borers but were less effective against gall midge compared to recommended insecticides. In all these studies, standard check insecticide treatments yielded significantly higher than neem formulations (Korat *et al.,* 1999; Dash *et al.*, 2001; Multani *et al.,* 2002). However, there are also few studies reporting the superiority or parity of commercial neem formulations in their performance compared to the recommended insecticides both in terms of reducing pest incidence and resulting in higher yields (Kaul and Sharma, 1999; Prasad *et al.*, 2004).

Studies on safety of neem formulations to natural enemies

There has been a general impression that neem and other plant products are safe to non target organisms. But, studies on impact of neem formulations on natural enemies (i.e., beneficial predators and parasitoids that attack pests) have documented effects ranging from harmless to adverse (Lim Guan Soon and Bottrell, 1994). Crude formulations of neem such as neem oil, neem cake and other non-edible oils and cakes have been reported to be safer to natural enemies compared to synthetic insecticides (Dash *et al.*, 2001). Investigations carried out at DRR, Hyderabad have revealed that commercial neem formulations such as Neemax, Rakshak, and Fortune Aza were also safer to planthopper predators like velid bug, *Microvelia douglasi atrolineata* and mirid bug, *Cyrtorhinus lividipennis* and egg parasitoid, *Trichogramma japonicum* (Jhansilakshmi *et al.,*1997a, 1997b & 1998). However, Neem Gold, Neem Azal and NG4 resulted in high mortality of velid predator (Jhansilakshmi *et al.,* 1997a). Other workers have also reported the safety of Fortune Aza to egg parasitoids (Borah *et al.,* 2001; Srinivasan *et al.*, 2001).

Evaluation of neem formulations in combination with other components of IPM

In order to make best use of the neem formulations in IPM there is a need to optimize the number as well as timing of their applications to derive maximum benefits. Trials conducted at DRR, Hyderabad revealed that carbofuran 3G @ 0.75 kg a.i./ha applied at 25 DAT followed by two sprays of NG 4 (2%) at 50 and 70 DAT reduced pest incidence and increased grain yield similar to three sprays of monocrotophos (0.4 kg a.i./ha/ application) at 25, 50 and 70 DAT revealing the possibility of reducing environmental contamination without lowering either pest control efficiency or grain yield. Replacement of monocrotophos at 50 DAT with NG 4 maintained similar level of pest control and grain yield. However, three NG 4 applications at 25, 50 and 70 DAT resulted in lower insect pest control and grain yield (Krishnaiah *et al.*,2000). Increase in the effectiveness of neem products when combined with insecticides has also been reported (Sharma and Kaul, 2003). In deep water rice also, integrated treatments with neem components plus one or two synthetic chemical applications were found very effective in controlling the pest population build up as compared to chemical control (Chakraborti, 2003). In another field study, combination of botanicals with egg parasitoid, *Trichogramma japonicum* reduced populations of both stem borer and leaf folder as well as resulted in conservation of spider population, compared to insecticidal treatments (Sher Singh *et al.*, 2008). Neem formulations have also been found quite useful in reducing disease incidence in addition to insect pests when integrated with other non-pesticidal components of IPM. Dodan and Roshan Lal (1999) reported that combination of nimbecidine application with pre-transplanting incorporation of burnt rice husk and release of egg parasitoid, *Trichogramma japonicum* reduced the incidence of neck blast disease as well as stem borer damage in rice on par with that of recommended pesticide combinations. Evaluation of different IPM modules in farmers fields at Karakkad village, Pattambi, Kerala over three years showed that IPM module comprising of alternate spraying of econeem formulation with ecofriendly insecticides coupled with release of egg parasitoids against leaf folder and monitoring of yellow stem borer with sex pheromone traps resulted in significant reduction of stem borer and leaf folder incidence resulting in highest yield and cost benefit ratio (Karthikeyan *et al.*, 2010).

Future Scope of biopesticides in rice IPM

Over the past 25 years, the research on biopesticides has evolved towards being more ecologically holistic and more oriented towards both production systems and industry’s concerns. In the rice IPM scenario, biopesticides provide environmental friendly options in many ways. The relatively shorter duration of persistence of the available botanicals can be suitably exploited to prevent secondary pest out breaks resulting from misuse of synthetic insecticide application. Synthetic pesticides with single active principle are likely to induce the development of resistance in insects. Botanicals on the other hand contain complex array of compounds with multiple effects and there is less likelihood of development of resistance. Therefore, wherever possible, botanicals can be alternated with synthetic pesticides to hinder the development of insecticide resistance. Concurrently, with advances in development of latest and more efficient analytical techniques, research on identification of newer active principles of these biopesticides may lead to synthesizing newer molecules with better efficacy and enhanced persistence under field conditions.

But the biopesticides face a number of constraints in their development, manufacture and utilization. Lack of multidisciplinary research, inadequate public private partnerships and poor understanding of their quality aspects, are the critical bottlenecks. Generally, farmers are accustomed to quick knock-down effects of pesticides. Therefore, they may not be satisfied with the slower action of biopesticides. There is, thus, a need to educate farmers about the special behavioural effects of these products and also create awareness among extension specialists and policy makers for the potential utilization of biopesticides. More focused research efforts in production, formulation and development of effective delivery systems are needed to effectively harness their potential and convince the farmers about their role as equally efficient and eco-friendly alternatives to conventional chemical pesticides.

In the recent years, there has been a spurt in efforts to develop organic pest management methods in view of the strong influence and growth of the organic foods market in the developed countries and biopesticides do find a place in this context. In India also, there has been a distinct trend in the decreased use of conventional chemical insecticides with a concomitant but gradual increase in consumption of biopesticides (Fig 2).

There are also reports of rice pests already developing resistance to even newly introduced agrochemicals leading to synthetic chemicals being registered at a slower rate than in the past. This situation has helped to reopen the market for a new generation of biopesticides. With fast paced changes in development of effective delivery systems and possibility of identifying newer potential biomolecules, a relook at the utility of biopesticides may be worthwhile in future.

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Table 1: Efficacy of neem products evaluated against insect pests of rice (Anand Prakash *et al.*, 2008)

Neem product & dose/ conc.	Type of application	Target insects	Biological activity	References
Neem oil	Spraying	Hydrellia phillipina	Antifeedant	Murthy (1975)
Neem oil	Spraying	BPH	Strong repellency	Balasubramanian (1979)
Neem oil 10%	Spraying	LF and GLH	Antifeedant ; Reduced life span	Mariappan *et al*. (1982a)
Neem oil	Spraying	GLH & RTV	Population reduction	Mariappan and Saxena (1983)
Neem oil	Neem oil coated urea	Hydrellia philippina, N. virescens and BPH	Reduced incidence	Krishnaiah and Kalode (1984)

Neem oil		L.oratorius	Deformity	Saxena *et al.* (1985)
Neem coated urea	Soil application	GM, GLH & RLF	Reduced incidence	David (1986)
Neem Seed Kernel Extract (NSKE)	Spray application using ULV sprayer	BPH, RLF	Checked incidences of the test insects	Rajasekaran *et al.* (1987)
Neem oil		BPH	Insecticidal activity	Velusamy *et al.* (1987)
Neem oil (1%), neem cake extract(5%)	Spraying	BPH and WBPH	Reduced emergence	Ramaraju & Sundarababu (1989)
NSKE 5%+0.16% teepol	Spraying	LF	Reduced population significantly	Mohan and Gopalan (1990)
3% neem oil	Spraying	GM	Reduced infestation	Samalo *et al.* (1990)
1-4% neem oil	Spraying	LF and YSB	Reduced incidences	Singh *et al.* (1990)
5% neem oil	Spraying	L. acuta	Reduced population	Gupta *et al.* (1990)
3% Neem kernel powder	Spraying	N. virescencs	Inhibited nymphal growth	Krishnaiah and Kalode (1990)
Neem cake @150 kg/ha + 3% neem oil spray	Soil application and Spraying	LF	Effectively checked insect infestation	Krishnaiah et al. (1990), Krishnaiah and Kalode, (1990)
Neem cake with urea	Soil application	GLH and WBPH	Reduction in population	Viswanathan & Kandiannan, (1990)
2% neem oil	Spraying	LF, Hieroglyphus banian	Reduced infestation	Mohan *et al.* (1991)
Neemax	Spraying	WBPH	Reduction in pest incidence	Shukla *et al.* (1991)
Welgro	Spraying	WBPH	Reduction in pest incidence	Shukla *et al.* (1991)

Neem oil @7.5 kg/ha	Spraying	BPH and WBPH	Reduced infestation	Sontakke. (1993)
Welgro2%	Spraying	GM and YSB	Reduced incidence	Nanda *et al.* (1993)
Nemidin 1000 ppm	-	WBPH	Inhibition of larval development	Nelson *et al*. (1993)
Neem oil	Spraying	Gall midge, stem borer, leaf folder and WBPH	Reduction in damage and effect on predators	Sontakke (1993)
Neem oil (3%) and neem seed kernel extract (5%)	Spraying	WBPH and GLH	Reduction in populations	Shukla and Kaushik (1994)
Neem oil	Spraying	WBPH	Reduction in population	Sontakke *et al*. (1994)
Neem seed kernel extract and neem cake extract	Seedling root dip – Greenhouse study	GLH	Reduction in population and effect on growth and emergence	Dash and Senapati (1994)
Neem cake @150 kg/ha	Soil application	Hydrellia philippina	Reduce damage of whorl maggots	Bhatia *et al*. (1994)
0.5 and 1.0% Achook	Spraying	L. acuta	Effectively controlled the pest	Prakash and Rao (1994)
Margoside CK and Margoside OK 1%	Spraying	5th instar BPH	57-80% mortality	Jena and Dani (1994)
Neem seed kernel extract (5%)	Spraying	Leaf folder	Reduction in damage	Latha *et al.* (1994)
Neem seed kernel extract (5%)	Spraying	Leaf folder	Reduction in damage	Latha *et al.* (1994)
Neem cake	Pot experiments with pellets	WBPH	Persistent toxicity	Logiswaran and Venugopal (1995)
Neem cake, neem seed kernel extract (5%), neem leaf decoction and neem oil (3%)	Soil application and spraying	Leaf folder	Reduction in leaf damage	Ambethgar (1996)

Neem oil and neem cake	Seedling root dip, soil application and spray	GLH, BPH and predators of BPH	Reduction in incidence of GLH and BPH. Little effect on predators.	Babu *et al*. (1998)
Nimbecidine, Neemax, Neem Gold, Neem Azal T/S and Fortune Aza	Spraying	Leaf folder, WBPH and stem borer	Reduction in pest incidence	Korat *et al* ,(1999)
Neem oil based formulations	Spraying	GLH and rice yellow dwarf disease	Reduction in GLH survival and incidence of disease	Rajappan *et al*. (1999)
NSKE 5%, Neem azal F 5%, Neem Azal T/S	Spraying	LF and egg parasitoid, Trichogramma chilonis	Contact toxicity	Prabal Saikia and Parameswaran (2001)
Neemazal	Spraying	Hispa	Reduction in damage	Sharma and Kaul (2003)
Neem seed kernel extract	Laboratory studies	Leaf folder	Effect on gut enzymes	Nathan *et al*. (2004)
Neem oil, Neem seed kernel extract and neem seed kernel powder	Spraying	Gundhi bug	Reduction in bug population	Singh (2006)
Neem limonoids	Laboratory studies	Leaf folder	Toxicity and behavioural effects	Nathan *et al*. (2006)
NSKE 5%, Neem Oil 3%, Neem Leaf Extract 3%	Seed Treatment, Seedling root dip and Foliar spray	WBPH	Effects on survival and growth index	Sujeetha (2008)
Multiplex	Spraying	Gundhi bug	Reduction in grain damage	Singh *et al*. (2009)

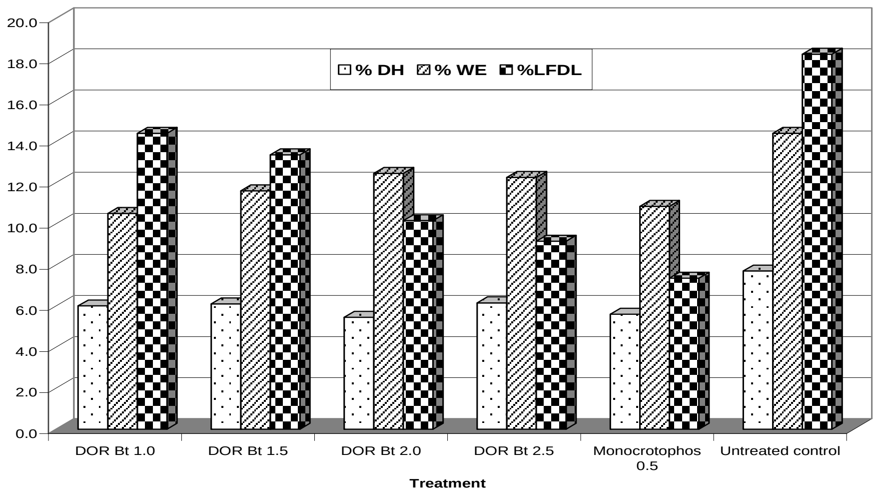

Figure 1: Efficacy of DOR Bt formulation against major rice pests (AICRIP, 2007-08)

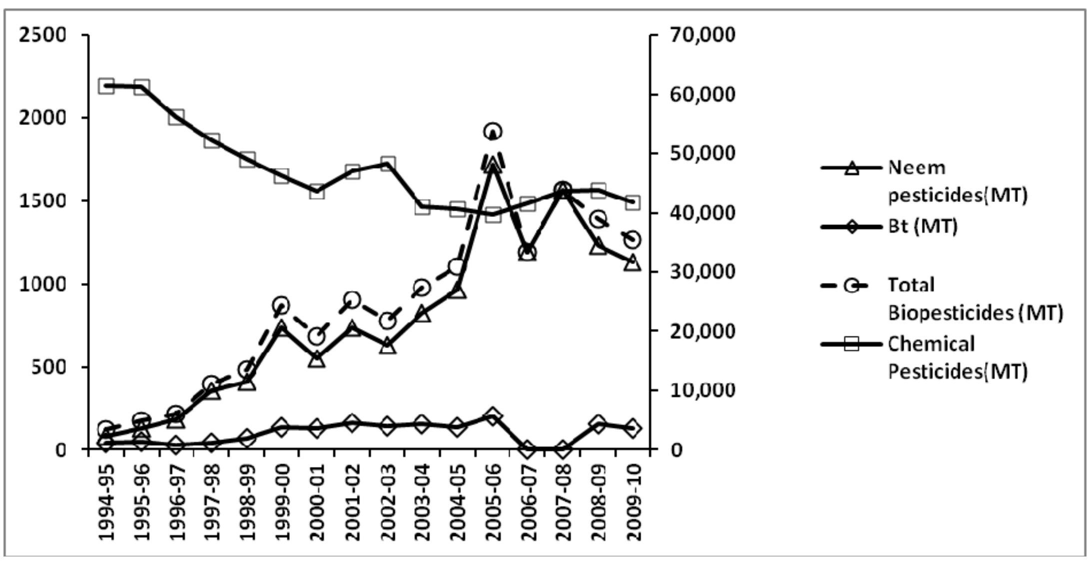

Figure 2: Consumption of pesticides (Metric Tonnes-MT) in India (1994-2010)

(Directorate of Plant Protection, Quarantine & Storage, Faridabad)

Assessment of Variability of Rice (*Oryza sativa* L.) Germplasm using Agro-morphological Characterization

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Abstract

The present study was carried out to characterize seven hundred eighty-two rice germplasm accessions on the basis of twenty-nine morphological and eight agronomical traits. Most of the morphological characters showed variation in different accessions except leaf : collar leaf : ligule and leaf : shape of ligule. A significant amount of variation was displayed for most of the agronomical traits examined. After evaluation of 782 accessions for eight quantitative characters, on the basis of mean values, top ten accessions were identified for the yield ancillary traits. These can be used to identify phenotypically divergent sources for traits of interest in breeding programmes.

Key Words: Agro-morphological characters, germplasm, variability, rice

Rice (*Oryza sativa* L.) is the world's most important cereal crop and serves as the primary source of staple food for more than half of the global population (Emani *et al.,* 2008). The large scale spread of modern, high yielding varieties has replaced the traditional varieties especially in the irrigated rice ecosystem leading to reduced genetic base and thus increased genetic vulnerability. In past few decades, increase in share of high yielding varieties and shrinkage in the area of local varieties have been reported in India (Hore 2005; Rana *et al*., 2009) as well as in several other countries (Chaudhary *et al*., 2006; Itani, 1993). There is an urgent need to broaden the genetic base of the important crop by introgressing genes from diverse sources. Thus, there is a need to collect, exploit and evaluate the untapped germplasm. In this context, an attempt was made to characterize a set of rice germplasm accessions for different morphological and agronomic trials and to identify the variability available in the collection.

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Materials and Methods

The material for the present investigations consisted of 782 rice germplasm accessions received from DRR Hyderabad and was evaluated under Multi location trial (MLT) during *kharif* 2011 at IGKV, Raipur. Each entry was sown in a plot comprising three rows having three meter length at spacing of 20 cm between rows and 15 cm between plants. The recommended agronomical practices were followed to raise good crop in the season. Observations were recorded on five randomly chosen plants of each accession for thirty-seven morphological and agronomical traits. The traits studied were Basal leaf: sheath colour, Leaf: intensity of green colour, Leaf: anthocyanin colouration, Leaf sheath: anthocyanin colouration, Leaf sheath: intensity of anthocyanin colouration, Leaf: pubescence of blade surface, Leaf: auricles, Leaf: anthocyanin colouration of auricles, Leaf: collar, Leaf: anthocyanin colouration of collar, Leaf: ligule, Leaf: shape of ligule, Leaf: colour of ligule, Culm: attitude, time of 50% heading, Flag leaf: attitude of blade, Lemma: anthocyanin colouration of keel, Lemma: anthocyanin colouration of area below Apex, Lemma: anthocyanin colouration of apex, Spikelet: colour of stigma, Stem: length, Stem: anthocyanin colouration of nodes, Stem: intensity of anthocyanin colouration of nodes, Stem: anthocyanin colouration of internodes, Panicle: length of main axis, Panicle: curvature of main axis, Panicle: number per plant, Lemma and palea: colour, Panicle: awns, Panicle: presence of secondary branching, Panicle: attitude of branches, Panicle: exsertion, Time of maturity, Grain: weight of 100 fully developed grains, Grain: length, Grain: width and Decorticated grain: colour. Accessions were characterized using morpho-agronomic descriptors according to DUS guidelines (DRR, 2006). Frequency distribution was computed to categorize the accession into different classes. Simple statistics (means, ranges) was calculated to have an idea of the level of variation.

Results and Discussion

(A) Morphological characterization: Qualitative characters are important for plant description (Kurlovich, 1998) and mainly influenced by the consumers preference, socio-economic scenario and natural selection (Hien *et al.,* 2007). Frequency distribution for 29 qualitative traits is depicted in Table 1 and its graphical representation of frequency distribution showed in Figure 1. Most of the morphological characters showed variation in different accessions except Leaf:collar, Leaf :ligule and Leaf : shape of ligule. A majority of accessions were found to possess Basal leaf: sheath colour (72% green), Leaf: intensity of green colour (60% dark green), Leaf: anthocyanin colouration (90% absent), Leaf sheath: anthocyanin colouration (82 % absent), Leaf sheath: intensity of anthocyanin colouration (83% very weak), Leaf: pubescence of blade surface (57% medium), Leaf: auricles (99.9% present), Leaf: anthocyanin colouration of auricles (59% light purple), Leaf: anthocyanin colouration of collar (90% absent), Leaf: colour of ligule (58% white), Culm: attitude (69% semi erect), Flag leaf: attitude of blade (75% semi erect), Lemma: anthocyanin colouration of keel (88% absent/very weak), Lemma: anthocyanin colouration of area below Apex (87% absent), Lemma: anthocyanin colouration of apex (72% absent), Spikelet: colour of stigma (68% white), Stem: anthocyanin colouration of nodes (94% absent), Stem: intensity of anthocyanin colouration of nodes (53% medium), Stem: anthocyanin colouration of internodes (875 absent), Panicle: curvature of main axis (57% semi erect), Lemma and palea: colour (69.5% straw), Panicle: awns (91% absent), Panicle: presence of secondary branching (99% present), Panicle: attitude of branches (49.5% semi erect to spreading), Panicle: exsertion (57% well exserted) and Decorticated grain: colour (74% white). Similar type of work was also reported by Bisne and Sarawgi (2008) and Moukoumbi *et al.* (2011). Based on the morphological descriptors 782 accessions were classified for 29 characters. Some of the unique accessions with distinct features are presented in Table 2.

(B) Agronomical characterization:

Rice accessions were evaluated for agronomical traits viz., time of 50% heading, Stem: length, Panicle: length of main axis, Panicle: number per plant, Time of maturity, Grain: weight of 100 fully developed grains, Grain: length, Grain: width from five competitive plants of middle row of each entry.

Time to 50 % heading: It had mean value of 110 days and a wider range of 66-157 days. Almost 50% of the lines fall in the range of medium to late group (Fig. 2), whereas IC 464013 and IC 577310 accessions were found to be very early in duration with days to 50% heading of 66 and 68 days, respectively.

Plant height: It had wider range (73-190 cm) of variation with a mean value of 144.26 cm. Ali *et al*. (2000) have observed relatively greater range in plant height than the other characters. Plant height in rice is a complex character and is the end product of several genetically controlled factors called internodes (Cheema *et al*., 1987). IC 576897 (73 cm) and IC 576902 (89 cm) were the two accessions which falls under very dwarf group. More than 50% accessions were having plant height in the range of 131-150 cm and can be grouped as tall. Very few accessions exhibited semi dwarf nature and about 100 accessions showed semi tall stature. Reduction in plant height may improve their resistance to lodging and reduce substantial yield losses associated with this trait (Abbasi *et al*., 1995).

Panicle length: It exhibited reasonable amount of variation with range values of 19-34 cm. The average panicle length was 27.13 cm long. Most of the accessions fall under the range of 26-30 cm panicle length. The maximum panicle length was observed in IC 466454. Although it contributes positively yet maximum panicle length is not the only factor responsible for higher grain yield (Abbasi *et al*., 1995). So panicle length alone does not determine the high grain yield as traits such as grain size, grain shape, higher number of tillers/plant, longer panicles and greater number of grains/panicle ultimately contribute to higher grain yield (Akram *et al*., 1994).

Number of productive tillers per plant: It is another yield attributing trait (Abbasi *et al*., 1995). A great variability with high range (2-19.33) and mean value of 6.01 was exhibited for number of productive tillers/plant. IC 462373 had maximum value(19.33).

Days to maturity: It also exhibited high range (86-184 days) with a mean of 125.02 days IC

464013 had shorter maturity period (86 days) representing earliness. Minimum value for days to maturity represents that the variety has a benefit of early ripening. Most of the lines fall under mid early followed by medium and late duration.

100-grain weight: It is also a yield-attributing trait (Abbasi *et al*., 1995). Most of the lines were in the range of 2.1 – 2.5 g. Lines with high grain weight (> 3g) were also observed in this set of germplasm (Fig.2). IC 463274 had maximum 100 grain weight (4.32 g).

Grain length: Grain length is an important quality parameter. Rice grain can be classified as extra long, long, medium and short (Akram *et al*., 1994). It exhibited high range (6.0-11.8 mm) with mean of 8.4 mm. In the present material, more than 80% accessions falls in short to medium group, whereas few of the accessions were observed with long grain. IC464907 was observed with maximum grain length (11.8 mm).

Grain width: It exhibited high range (2-4.4 mm) with mean of 2.6 mm. In the present material, most of the lines were in the range of 2.1 – 3.0 mm. IC 460013 was observed with maximum grain width (4.4 mm).

After evaluation of 782 accessions for eight quantitative characters, on the basis of mean values, top ten accessions were identified for the yield ancillary traits (Table 3). IC 462373 (19.33) had the highest number of effective tillers per plant followed by IC 463424 (14.33). Similarly, IC 463274 (4.32 g) had the highest rank for 100 grain weight followed by IC 466455 (4.00 g). Identifying germplasm accessions for different agronomical characters in phenotypically divergent sources would help in prebreeding and breeding programs.

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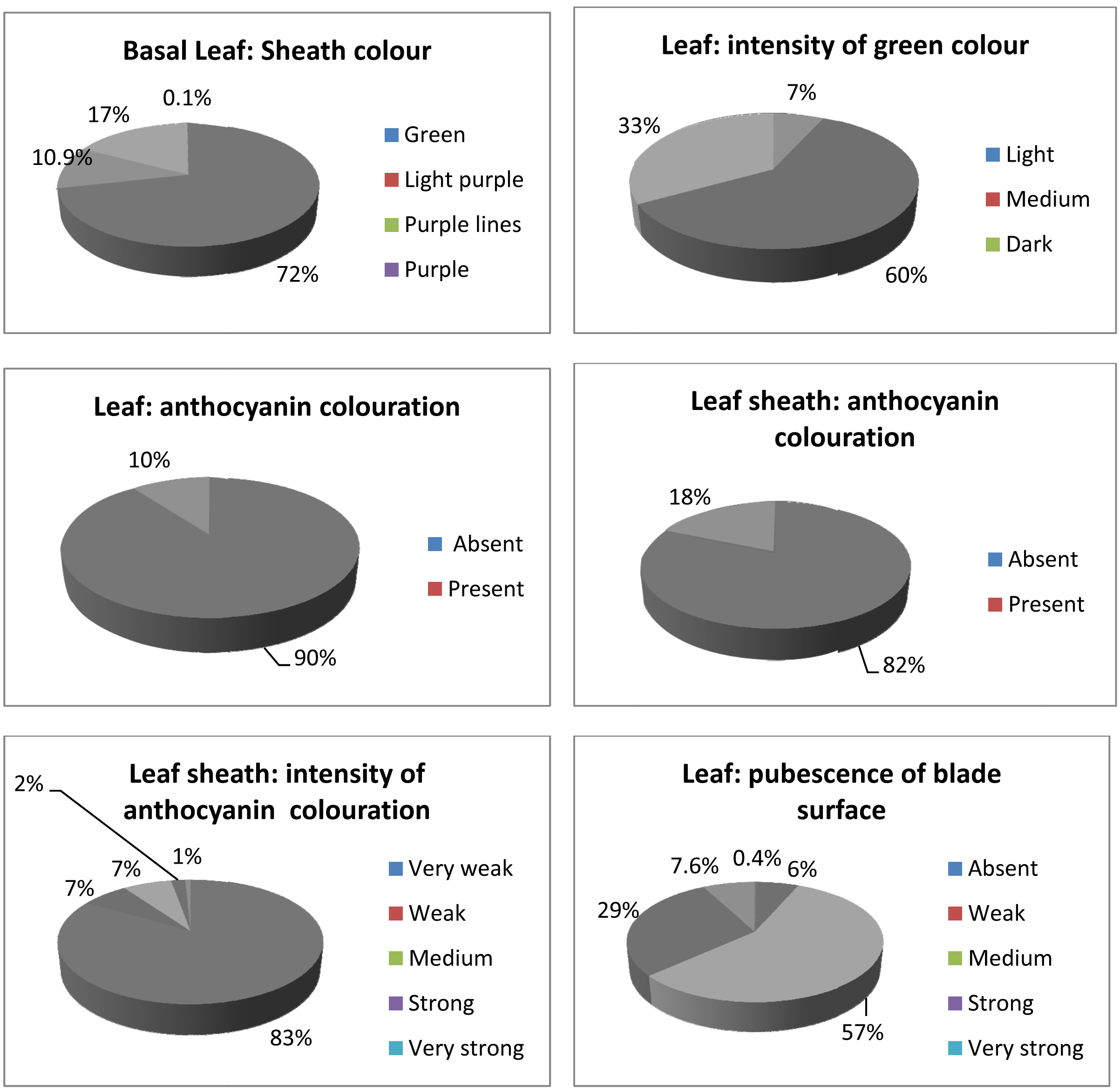
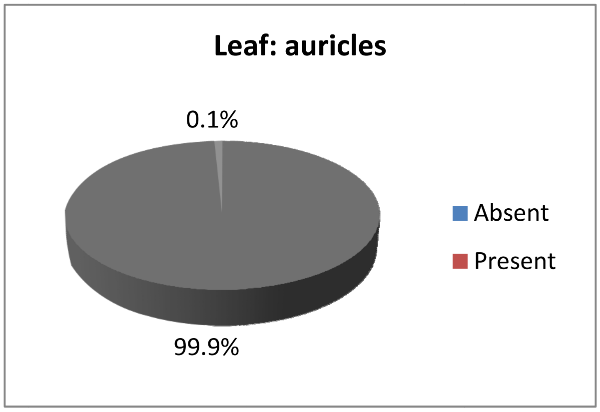
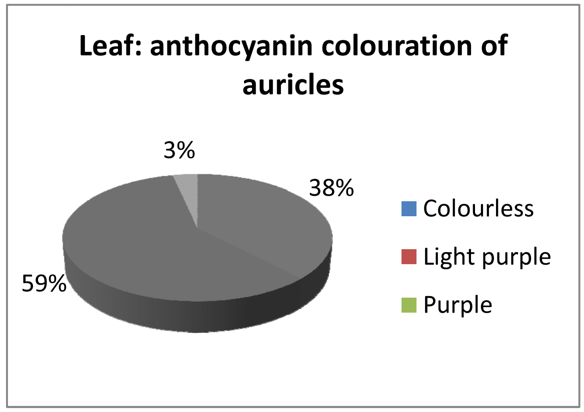
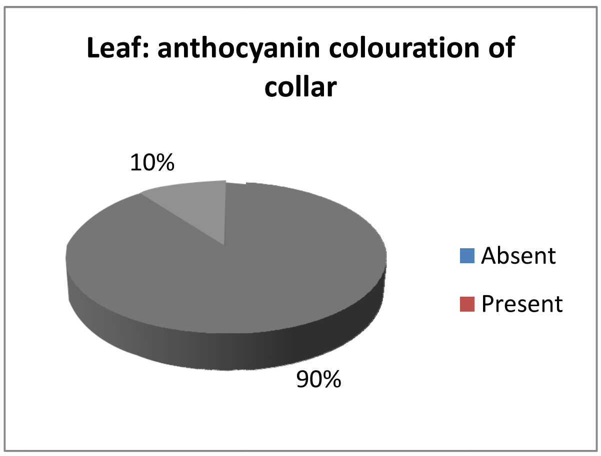
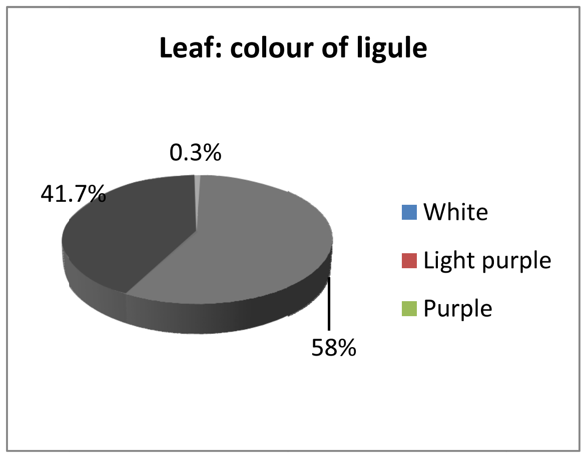
Figure 1: Frequency distribution of important morphological characters

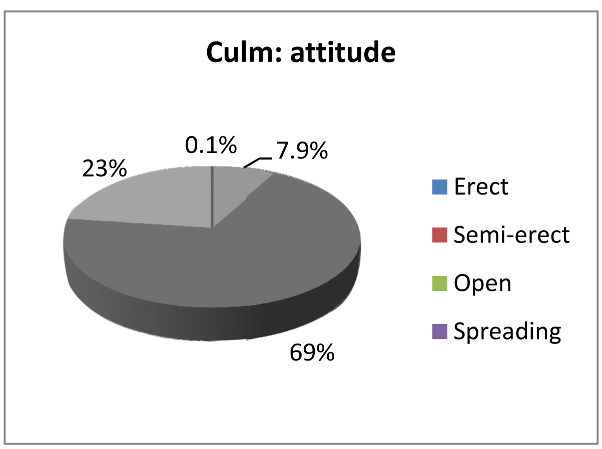


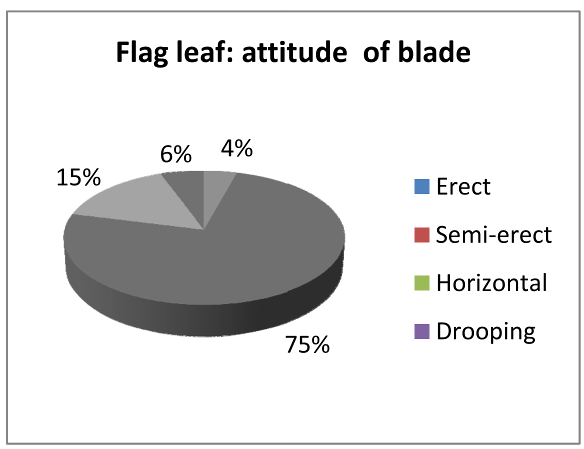

Leaf: auricles
0.1%
99.9%
Absent
Present

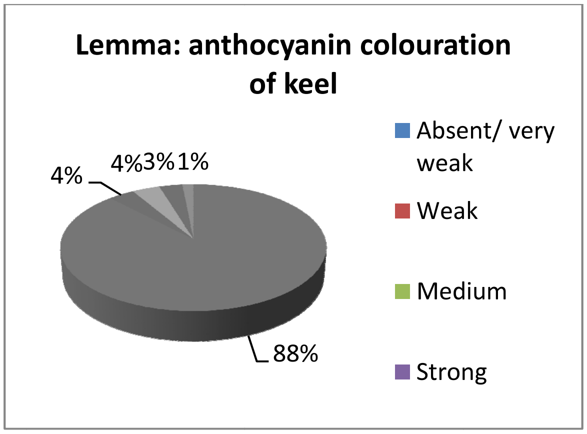

Leaf: anthocyanin colouration of auricles
3%
38%
59%
Colourless
Light purple
Purple

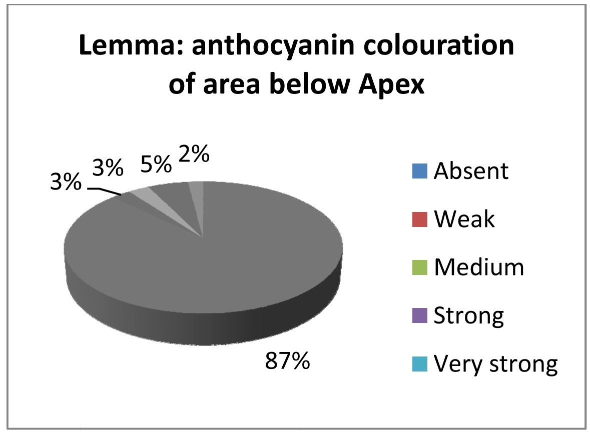

Leaf: anthocyanin colouration of collar
10%
90%
Absent
Present

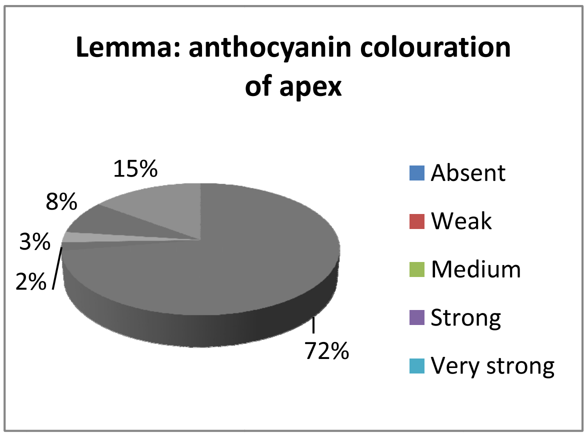

Leaf: colour of ligule
0.3%
41.7%
58%
White
Light purple
Purple

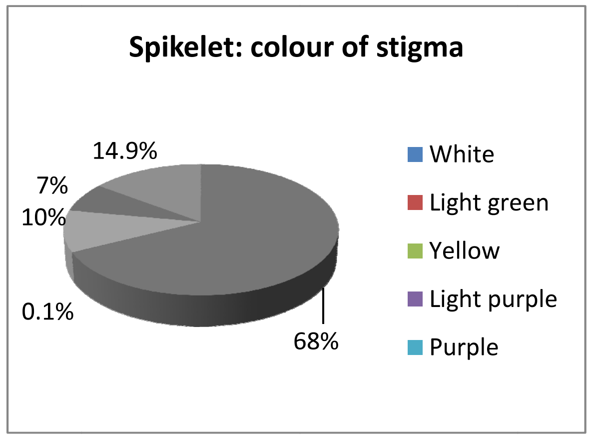

Culm: attitude
0.1%
7.9%
23%
69%
Erect
Semi-erect
Open
Spreading

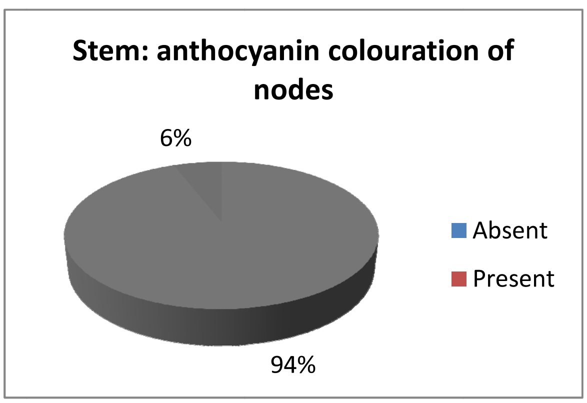

Flag leaf: attitude of blade
6%
4%
15%
75%
Erect
Semi-erect
Horizontal
Drooping

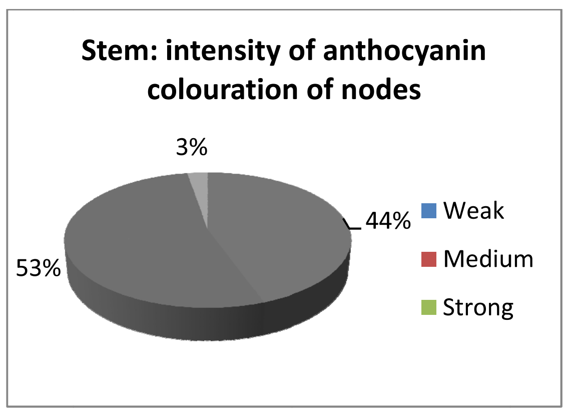

Lemma: anthocyanin colouration of keel
4%
4%3%1%
88%
Absent/ very weak
Weak
Medium
Strong

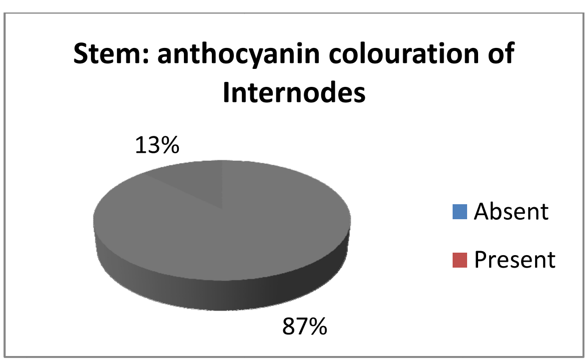

Lemma: anthocyanin colouration of area below Apex
3%
3%
5%
2%
87%
Absent
Weak
Medium
Strong
Very strong

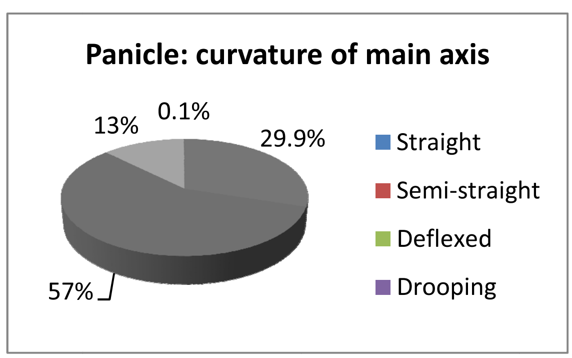

Lemma: anthocyanin colouration of apex
15%
8%
3%
2%
72%
Absent
Weak
Medium
Strong
Very strong

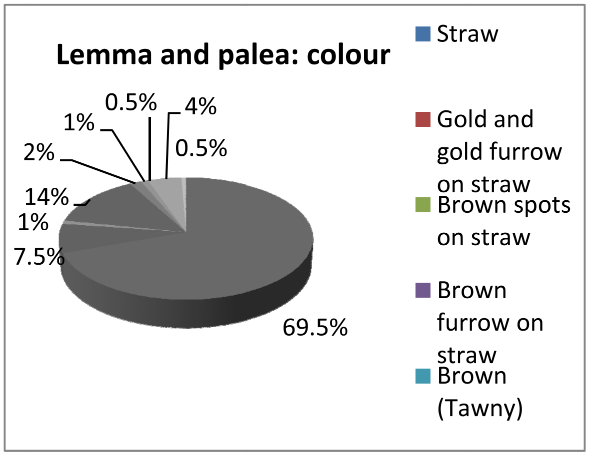

Spikelet: colour of stigma
14.9%
7%
10%
0.1%
68%
White
Light green
Yellow
Light purple
Purple

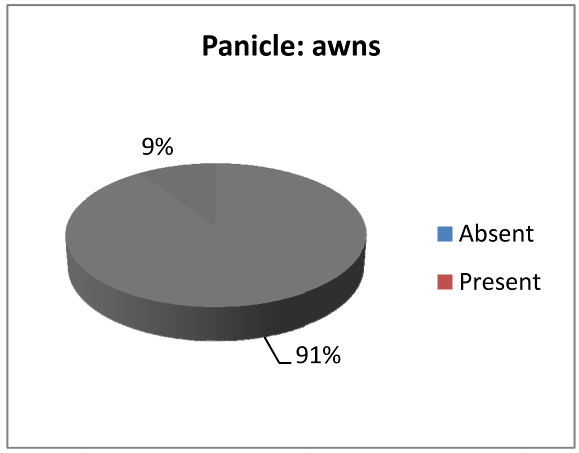

Stem: anthocyanin colouration of nodes
6%
94%
Absent
Present

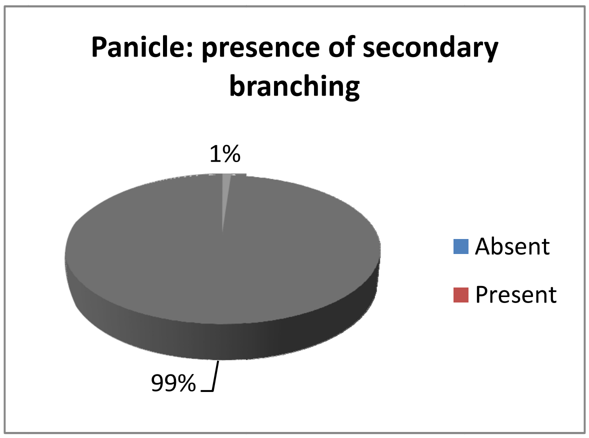

Stem: intensity of anthocyanin colouration of nodes
3%
44%
53%
Weak
Medium
Strong

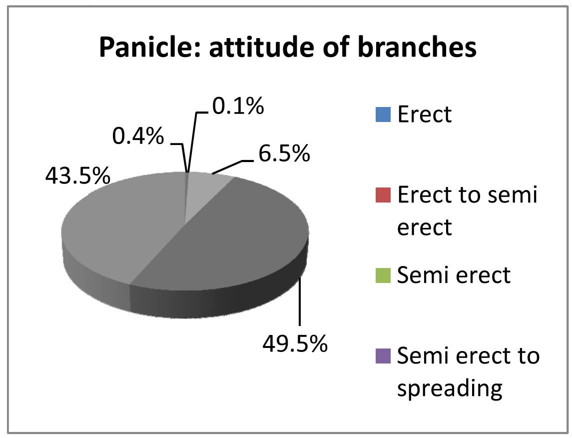

Stem: anthocyanin colouration of Internodes
13%
87%
Absent
Present

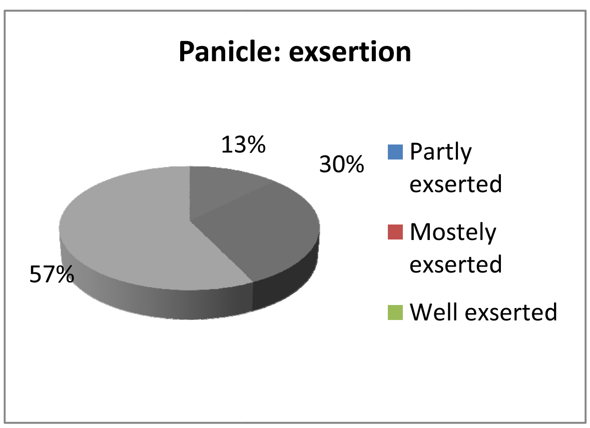

Panicle: curvature of main axis
13%
0.1%
29.9%
57%
Straight
Semi-straight
Deflexed
Drooping


Lemma and palea: colour
0.5%
4%
1%
0.5%
2%
14%
1%
7.5%
69.5%
Straw
Gold and gold furrow on straw
Brown spots on straw
Brown furrow on straw
Brown (Tawny)


Panicle: awns
9%
91%
Absent
Present


Panicle: presence of secondary branching
1%
99%
Absent
Present


Panicle: attitude of branches
0.1%
0.4%
6.5%
43.5%
49.5%
Erect
Erect to semi erect
Semi erect
Semi erect to spreading


Panicle: exsertion
13%
30%
57%
Partly exserted
Mostely exserted
Well exserted

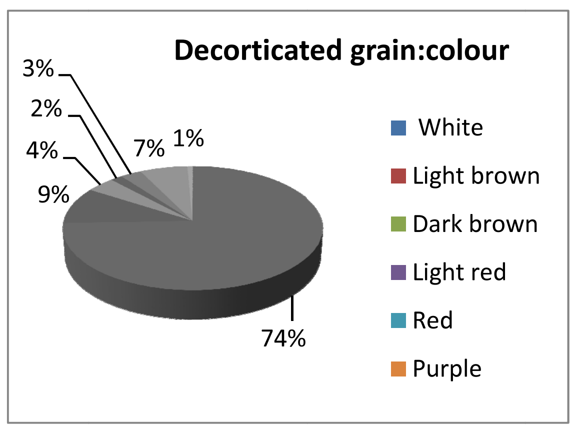

Decorticated grain:colour
3%
2%
4%
7%
1%
9%
74%
White
Light brown
Dark brown
Light red
Red
Purple

Figure 2: Frequency distribution of eight quantitative traits in rice accessions

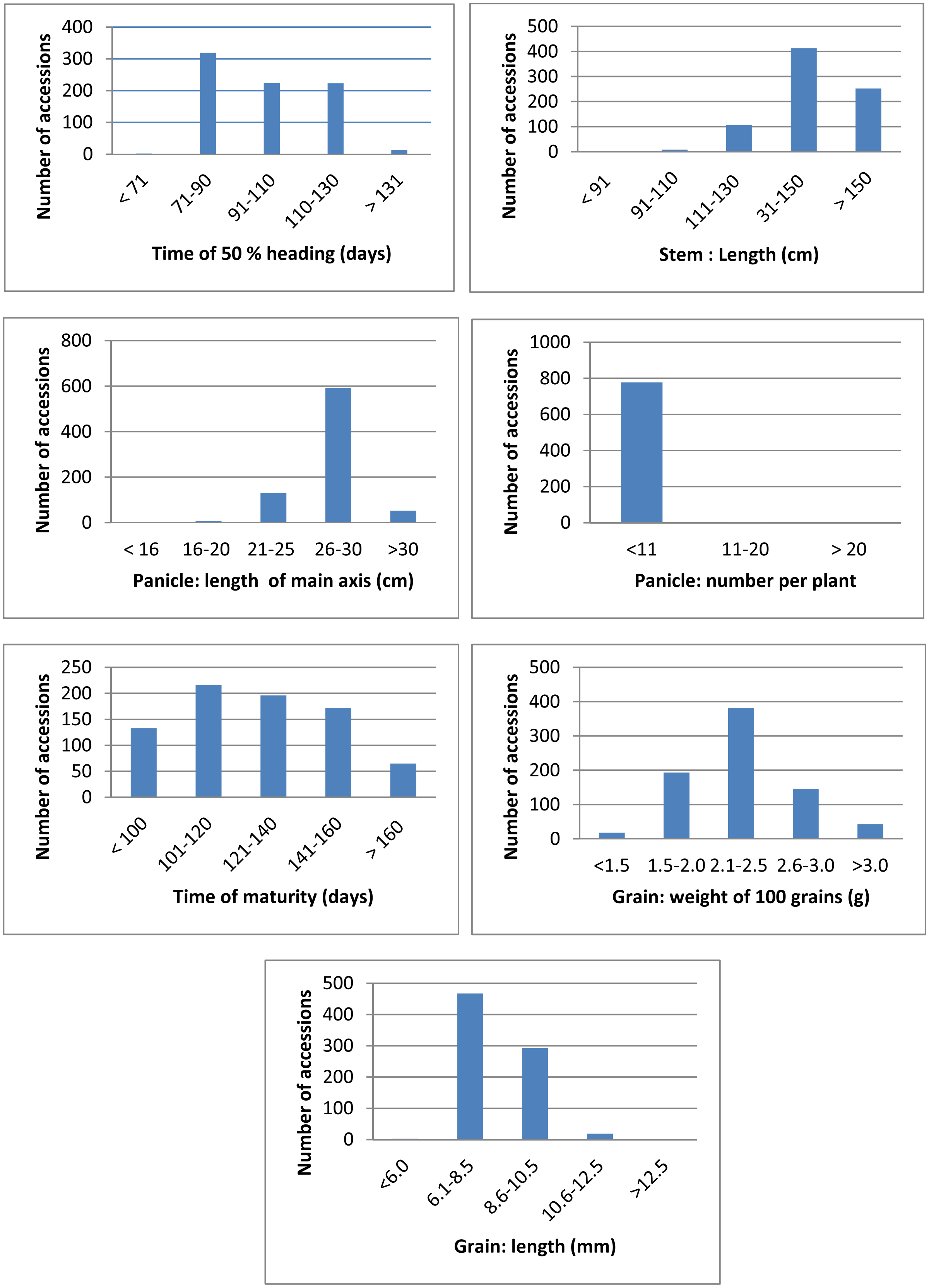


Table 1: Frequency distribution for agro-morphological characters in rice germplasm

S. No.	Morphological characters	Colour pattern/ type	Frequency
1	Basal leaf: sheath colour	Green	560
		Light purple	86
		Purple lines	135
		Purple	1
2	Leaf: intensity of green colour	Light	52
		Medium	471
		Dark	259
3	Leaf: anthocyanin colouration	Absent	702
		Present	80
4	Leaf sheath: anthocyanin colouration	Absent	638
		Present	144
5	Leaf sheath: intensity of anthocyanin colouration	Very weak	653
		Weak	52
		Medium	55
		Strong	16
		Very strong	6
6	Leaf: pubescence of blade surface	Absent	3
		Weak	48
		Medium	444
		Strong	226
		Very strong	61
7	Leaf: auricles	Absent	1
		Present	781
8	Leaf: anthocyanin colouration of auricles	Colourless	295
		Light purple	460
		Purple	27
9	Leaf: collar	Absent	0
		Present	782
10	Leaf: anthocyanin colouration of collar	Absent	701
		Present	81
11	Leaf: ligule	Absent	0
		Present	782
12	Leaf: shape of ligule	Truncate	0
		Acute	0
		Cleft/split	782
13	Leaf: colour of ligule	White	454
		Light purple	326
		Purple	2
14	Culm: attitude	Erect	61
		Semi-erect	542
		Open	178
		Spreading	1
15	Time of heading (50% of plants with panicles)	Very early (< 71)	2
		Early (71-90)	319
		Medium (91-110)	224
		Late (110-130)	223
		Very late (> 131)	14

16	Flag leaf: attitude of blade (early observation)	Erect Semi-erect Horizontal Drooping	33 584 121 44
17	Lemma: anthocyanin colouration of keel	Absent/ very weak Weak Medium Strong Very strong	687 28 30 25 12
18	Lemma: anthocyanin colouration of area below Apex	Absent Weak Medium Strong Very strong	682 20 22 42 16
19	Lemma: anthocyanin colouration of apex	Absent Weak Medium Strong Very strong	566 16 20 64 116
20	Spikelet: colour of stigma	White Light green Yellow Light purple Purple	528 1 80 57 116
21	Stem: length (excluding panicle, excluding floating rice	Very short (< 91 cm) Short (91-110 cm) Medium (111-130 cm) Long (131-150 cm) Very long (> 150cm)	2 8 107 413 252
22	Stem: anthocyanin colouration of nodes	Absent Present	736 46
23	Stem: intensity of anthocyanin colouration of nodes	Weak Medium Strong	348 413 21
24	Stem: anthocyanin colouration of Internodes	Absent Present	684 98
25	Panicle: length of main axis	Very short (< 16 cm) Short (16-20 cm) Medium (21-25 cm) Long (26-30 cm) Very long (>30m)	0 7 131 592 52
26	Panicle: curvature of main axis	Straight Semi-straight Deflexed Drooping	234 449 98 1
27	Panicle: number per plant	Few (<11) Medium (11-20) Many (> 20)	777 4 1
28	Lemma and palea: colour	Straw	544

		Gold and gold furrow on straw Brown spots on straw Brown furrow on straw Brown (Tawny) Reddish to light purple Purple spots/furrow on straw Purple Black	60 7 108 13 8 4 33 5
29	Panicle: awns	Absent Present	708 74
30	Panicle: presence of secondary branching	Absent Present	6 776
31	Panicle: attitude of branches	Erect Erect to semi erect Semi erect Semi erect to spreading Spreading	3 1 53 386 339
32	Panicle: exsertion	Partly exserted Mostely exserted Well exserted	99 235 448
33	Time of maturity	Very early (< 100) Early (101-120) Medium (121-140) Late (141-160) Very late (> 160	133 216 196 172 65
34	Grain: weight of 100 fully developed Grains	Very low (<1.5g) Low (1.5-2.0 g) Medium (2.1-2.5 g) High(2.6-3.0 g) Very high (>3.0 g)	18 193 382 146 43
35	Grain: length	Very short (<6.00mm) Short (6.10-8.50mm) Medium (8.60-10.50mm) Long (10.60-12.50mm) Very long (>12.50mm)	3 467 293 19 0
36	Grain: width	Very narrow (<2.0mm) Narrow (2.1-2.5mm) Medium (2.6-3.0mm) Broad (3.1-3.5mm) Very broad (>3.5mm)	7 348 330 78 19
37	Decorticated grain:colour	White Light brown Variegated brown Dark brown Light red Red Variegated purple Purple Dark purple	582 75 0 31 13 23 0 52 6

Table 2: List of unique accessions for different morphological traits.

S. No.	Morphological characters	Colour pattern/ type	Unique accessions
1	Basal leaf: sheath colour	Purple	IC 577118
2	Leaf: auricles	Absent	IC 577313
3	Leaf: colour of ligule	Purple	IC 463034, IC 462482
4	Culm: attitude	Spreading	IC 462373
5	Spikelet: colour of stigma	Light green	IC 450281
6	Panicle: curvature of main axis	Drooping	IC 466429
7	Lemma and palea: colour	Black	IC 463055, IC463190, IC 462453, IC 577162, IC 463796
8	Decorticated grain:colour	Dark purple	IC 545203, IC 459732, IC 463233, IC 462481, IC 463457, IC 466621

Table 3: Top ranking accessions for yield ancillary traits.

S. No.	Plant height (cm)	Panicle length (cm)	No. of effective tillers per plant	Grain length (mm)	Grain width (mm)	100 grain weight (g)
1	IC 576897 (73.00)	IC 466454 (34.00)	IC 462373 (19.33)	IC464907 (11.8)	IC 460013 (4.4)	IC 463274 (4.32)
2	IC 576902 (89.33)	IC 463586 (33.67)	IC 463424 (14.33)	IC 464895 (11.4)	IC 463446 (4.1)	IC 466455 (4.00)
3	IC 577060 (91.67)	IC 462413 (33.33)	IC 462467 (11.67)	IC 463032 (11.4)	IC 466502 (4.0)	IC 576987 (3.83)
4	IC 466394 (96.00)	IC 464906 (33.33)	IC 462256 (10.67)	IC 462498 (11.4)	IC 577035 (3.9)	IC 577061 (3.70)
5	IC 462427 (96.33)	IC 576987 (33.00)	IC 463902 (10.67)	IC 466599 (11.3)	IC 463414 (3.9)	IC 466502 (3.69)
6	IC 576898 (97.00)	IC 577027 (33.00)	IC 463331 (10.33)	IC 545218 (11.2)	IC 463312 (3.8)	IC 466613 (3.65)
7	IC 464979 (105.00)	IC 463212 (33.00)	IC 463400 (10.00)	IC 463214 (11.2)	IC 577488 (3.8)	IC 462498 (3.58)
8	IC 462471 (106.67)	IC 462482 (32.67)	IC 463896 (10.00)	IC 463791 (11.2)	IC 462496 (3.7)	IC 466454 (3.55)
9	IC 463457 (109.00)	IC 463235 (32.67)	IC 463438 (9.67)	IC 463068 (11.2)	IC 462476 (3.7)	IC 463780 (3.52)
10	IC 576900 (109.33)	IC 463643 (32.67)	IC 463367 (9.33)	IRGC21088 (11.2)	IC 463419 (3.7)	IC 463414 (3.48)

Sustainability Index as an Aid for Determination of Genotypic Stability in Aromatic Rice (*Oryza Sativa L.*) under Transplanted Condition in South-Eastern Plain Zone of Rajasthan

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Abstract

An experiment was conducted during *kharif (*2006-2010) season to determine the sustainability index and genotypic stability of seven released rice varieties under transplanted condition of South-Humid plane Zone of Rajasthan. The highest sustainability index (%) and high mean yield was recorded in variety P-1121 (91.28 % and 4.65 t/ha) followed by P-2511 (89.88 % and 4.56 t/ha.), P-1460 (85.58 % and 4.38 t/ha) and Pusa Basmati-1 (86.55% and 4.11 t/ha), whereas moderate sustainability index was observed in Mahi Sugandha (73.92 %) and Taraori Basmati (73.53%). Based on high yield performance and sustainability index, varieties *viz.*, P-1121 (Pusa Sugandh-4)), P-2511 (Pusa sugandha-5) and P-1460 (Improved Pusa basmati-1) can be used as parent in future breeding programme.

Key words: Sustainability index, genotypic stability, aromatic rice, best performance and standard deviation.

Rice, *Oryza sativa* (2n=24) is the second most important cereal and stable food for more than one third of the world's population. Varietal adaptability to environmental fluctuations is important for the stabilization of crop production over both the region and years. An information on genotype x environment interaction leads to successful evaluation of stable genotype, which could be used for general cultivation. Yield is a complex quantitative character and is greatly influenced by environmental fluctuation; hence selection for superior genotype based on yield per se at a single location in a year may not be very effective. Thus, varietal stability is of paramount importance for stabilizing the production over region and seasons especially in decreased farm holdings and resource poor farmer conditions. This lays a heavy emphasis on developing technologies while keeping sustainability of small farmer and his resources as the top priority. In subsistence agricultural system, yield *per se* may be less important than reaching a certain yield level (Fox *et al*., 1997). Therefore, development of varieties and hybrids with stable performance is gaining ground to help achieve sustainability in agricultural production. To achieve this, first concept is to select the genotype with the smallest deviation from its production potential. The use of sustainability

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index in terms of varietal stability gives an indication about the stability of a variety across the location and over the years. In rice, phenotypic stability has been studied by various workers (Nurmalina 2008 and Baber *et al.*, 2009). However, the information on the use of sustainability index for assessment of varietal stability is lacking in rice. Hence the present investigation was undertaken to determine the sustainability index of seven aromatic rice genotypes evaluated for five consecutive years (2006-2010).

Materials and Methods

The experimental material consisted of six aromatic rice varieties namely, Pusa Basmati-1, Pusa Sugandh-3, Pusa Sugandh-4, Pusa Sugandh-5, Mahi Sugandh and Taraori Basmati (Pusa Basmati-1 and Taraori used as checks) were evaluated at Agricultiral Research Station, Ummedganj, Kota, Rajasthan in completely randomized block design with three replications with row to row spacing of 20 cm. and plant to plant spacing of 10 cm. The grain yield was recorded on plot basis and was estimated in tonnes/ha. The four year data on each variety were used for estimation of sustainability index. The sustainability index was estimated according to following formula used by other workers (Singh and Agarawal, 2003; Gangwar *et al*., 2004 and Tuteja, 2006).

Sustainability index =

$$\frac{\text{Average performance} - \text{Standard Deviation}}{\text{Best performance}} \times 100$$

The value of sustainability index were arbitrarily divided in to five group *viz*. very low (up to 45%), low (46– 60 %), moderate (61-75%), high (76-90) and very high (above 90%).

Results and Discussion

The yield differences were found to be significant over the years, indicating genetic difference among the varieties studied. For drawing meaningful interference, the yield (best performance) and sustainability index could be divided into four groups as follows;

Yield (Best Performance)	Sustainability index	Remarks
High	High	Desirable
High	Low	Location specific
Low	High	Undesirable
Low	Low	Undesirable

In the present study (Fig-1), Pusa Sugandh-4 recorded highest grain yield and has highest sustainability index (4.89 t/ha and 91% respectively), indicating the best performance of this variety. The high level of best performance coupled with high value of sustainability index could be taken as the indication of close proximity between the best performance and the average performance over the years. This explains the good stable performance of Pusa Sugandh-4 over the years. The second best genotype was Pusa Sugandh-5 which recorded best performance of 4.81 t/ha and sustainability index of 90 percent. The variety Mahi Sugandh although recorded high yield of 4.43 t/ha, however its sustainability index was moderate indicating its inconsistent performance over the years. This variety gave the highest performance during the year 2010, thus it was adaptable to specific situation only. The yield performance and sustainability index of remaining genotypes were poor to average indicating their unstable performance over the years. From the present investigation, it's concluded that the variety Pusa Sugandh-4 was the most suitable followed by Pusa Sugandh-5, Improved Pusa Basmati-1 and Pusa Basmati-1. It is suggested that variety Pusa Sugandh-4, Pusa Sugandh-5 and Improved Pusa Basmati-1 can be used as a parents in future breeding programme for evolving genotypes with high sustainability of grain yield.

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.**Table 1: Estimation of sustainability index (%) for seven genotypes of aromatic rice**

Particulars / Year	**Grain Yield performance in different years (t/ha)**						
	Pusa Sugandh-4	Pusa Sugandh-5	Pusa sugandh-2	Improved Pusa Basmati-1	Mahi Sugandha	Pusa Basmati-1	Taraori basmati
2006	4.41	4.18	3.24	3.86	3.13	3.94	2.72
2007	4.65	4.53	3.46	4.15	3.54	3.86	3.05
2008	4.56	4.69	3.82	4.52	3.85	3.98	2.93
2009	4.72	4.81	3.59	4.65	3.78	4.45	3.36
2010	4.89	4.56	3.99	4.69	4.43	4.27	3.75
Mean yield (q/ha) over years	4.65	4.55	3.62	4.37	3.75	4.10	3.16
Standard deviation	0.18	0.23	0.29	0.35	0.47	0.24	0.40
Best performance (q/ha)	4.89	4.81	3.99	4.69	4.43	4.45	3.75
Sustainability index (%)	9.12	8.98	8.33	8.55	7.39	8.65	7.35

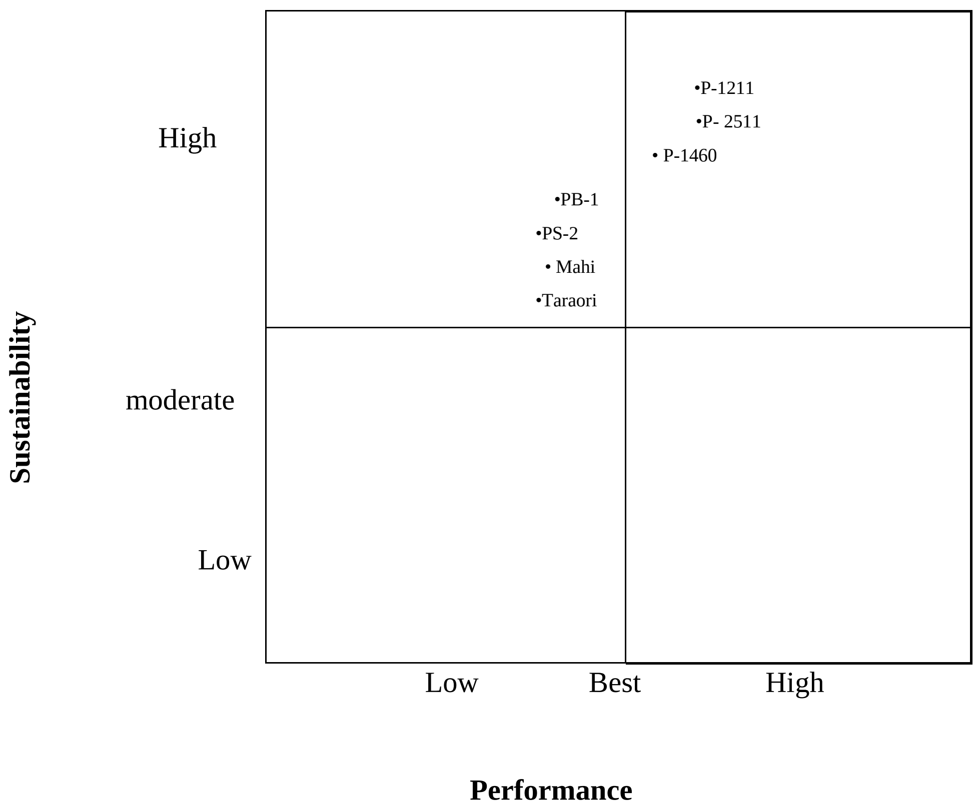

Figure 1: Grouping of genotypes as per their best performance and sustainability indices

Rice Genotypes Response to Mid Season Stress on Fertility and Yield at High Altitude

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Abstract

Altitudinal effect of mid season stress which coincided with microspore development stage to anthesis period was examined on 58 rice genotypes. Seeds were planted at the end of March. Mid season growth of plants coincided with high rainfall. An ideal situation of grain production in rice on high hills was determined by significant relation between spikelet fertility and grain yield while stress factors were identified by their significant association with environmental components. Except earliest among early (EEM) and late (LM) maturity group, a reduction in likelihood of these relationships was observed for other rice genotypes. It was presumed that physical separation of pollen grains with stigmas and/or more complex interaction between genotype and environmental factors perhaps constituted this relationship. Variation in soil temperature appeared as major limiting factors for EEM and LM genotypes. The distribution of root in soil, higher capacity of transport system during the period of reduced water uptake, osmotic adjustment of cell for greater water availability and increasing ability of phosphorylation bylight harvesting protein complex of PS II would be considered as effective measures to reduce stress factors on high hills. Regression analysis revealed that pre-fertilization development of carpel, determined grain yield among LM rice genotypes on high altitude.

Key words : Rice, high altitude, cold stress.

Altitudinal effect is an important stress on rice that results in delayed heading and yield reduction due to spikelet sterility, poor fertilization efficiency and impaired seed growth. It is presumed that a combined influence of both air and soil temperature affect the vegetation (Patil and Sinha, 2006) and imposes restriction on stable production of rice (Gunawardena et al., 2003) on high altitude areas of hills. On high hills, atmospheric temperature declines with increase in elevation (Schwerdtfeger, 1976) while heat conduction in soil is governed by the thermal properties (Koorevaar *et al*., 1983) that are strongly dependent on distribution, intensity and volume of rain fall received at growing site. In areas with cool spring, rice seeds are planted in May and only genotypes of medium or short duration can be grown, that results in reduction of grain

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yield. On higher altitude, planting of rice seeds in May is not preferred as daily average and minimum temperature fall below 15 and 10^{0}C, respectively during post-flowering period. This indicates that a coincidence of grain filling stage with the period of potential maximum photosynthesis and suitable temperature regime seems to be important for grain yield (Farrell et al., 2006) on high hills. On the contrary, rice plants are injured due to low temperature at the seedling stage when seeds are planted early spring (Andaya and Mackill, 2003). As the season progresses, rise in temperature and high intensity of sun light encourage pre-flowering growth of plants, while exposing the plant to cool summer damage (Yajima, 1996). The type of cold injury varies depending upon stress level and duration of exposure (Bertin et al., 1996) and becomes difficult to identify factor responsible for stress tolerance because genes contributing to vigour might be different from genes conferring tolerance (Zhang et al., 2005) and the traits that appear important in one environment may not always be important in other environment in determining the phenotype (Tanksley, 1993). High altitude genotypes have not contributed much to the ancestry of cultivated rice; therefore, identification of rice genotypes adapted to altitudinal variations has become important as potential source of genes tailored to confer tolerance to low temperature environments. Field evaluation is the only practical procedure to evaluate high altitude cold tolerance of rice. No attempt to relate these climatic factors to rice production was made for high hill condition in Uttarakhand state. In this investigation, rice genotypes response to mid season cold stress on spikelet fertility and yield was examined under rainfed condition at high altitude.

Materials and Methods

In this investigation a set of 58 temperate rice germplasm was considered for evaluation. This included exotic materials and local collection of land races from high altitude regions. The experiment was conducted for two successive years (2006-2007) at an elevation of 2100 m at Ranichauri (30^{0}18$'$ N and 78^{0}24$'$E) under rain fed condition. Seeds were planted early (March end) in a homogenous field. Experiment was laid out in randomized block design with 3 replications. Each plot consists of 4 rows of 4 m in length. Spacing between rows and plants was maintained at 0.20 and 0.15 m. To facilitate production of uniform plant stand excess plants were removed at seedling stage. Recommended dose of fertilizer were applied and scheduled plant protection measures were adopted to obtain disease free and healthy plants in field. The most vigorous 50 plants were selected at early vegetative growth on field and labeled properly at microspore development stage (MS) that was determined by the distance between the ligule of the flag leaf and that of the penultimate leaf (Yoshida, 1981), considering an interval of -1 cm (flag leaf ligule below the penultimate leaf ligule) as the indicative of beginning of this stage. In the present study, panicle developed on main shoot was examined. Time required to attain microspore development (MS), panicle emergence (PE) and anthesis (AN) stage on individual plant were recorded by careful observation at 3 days interval from 75 days after date of planting seeds (DP) on field. PE was determined by 25 % visibility of panicle above flag leaf ligule on main shoots while anthesis period (AN) was considered when anther burst in 25% of the visible spikelets present on a panicle. A sample of 30 good and healthy spikelets among 50 selected plants was harvested randomly at maturity for recording observation on grain yield (GY), per cent spikelt fertility (SF), 100 seed weight (SW) and length and breadth ratio of seeds (l:b). Per cent spikelet fertility was obtained by counting the number of filled grain (FG) and empty spikelets on individual spike and express as per cent of filled spikelets in relation to the total number of spiketlets (NS) present on a panicle. Information of environment components on growth and development of plant characters were obtained by collecting meteorological data from respective department of G.B.P.U.A.&T., situated at Hill Campus. Daily maximum and minimum air temperature (Mxt and Mnt respectively) accompanied with volume of rainfall (RF) received and relative variation in maximum and minimum soil temperature at three different depth viz., (ST_1, ST_2, ST_3 at 5, 10, 20 cm, respectively) were recorded. An estimation of average (Avt) and diurnal (Dut) variation of air temperature and average difference in maximum and minimum soil temperature at three different levels of depths (ST_1- ST_2, ST_2 – ST_3 and ST_1 – ST_3) were computed. Cumulative values of thermal time (express in degree days) were calculated for all components of air and soil temperature on individual rice genotypes at two different phenophase of crop growth viz., MS – PE and PE – AN. Total volume of rain fall experienced during respective stage of development was also determined for individual genotype. Six plant traits and 37 environment components (Table 1) at respective phenophase (MS-PE and PE-AN) were subjected to correlation analysis. Significant association between two variables was measured by *t* test. Since the place of origin of a variety is not a sufficient guarantee for possessing high cold tolerance (Ravilla et al., 1998) significant association between SF and GY was considered as major determinant for identifying favourable environment for crop growth on high hills. A reduction in likelihood of relationships between SF and GY was disallowed for consideration of study, while their (SF and GY) non-significant association with environment components had allowed to classify the rice genotypes into shorter range of different maturity groups and were subjected to correlation analysis afresh for second time to observe the significant influence of environment factors controlling the expression of SF and GY to individual sub-groups separately. In this investigation entire rice genotypes (T) were divided into early (EM, 104-130 days), medium (MM, 131-145 days) and late (LM, 146-165days) maturity groups depending upon time of panicle emergence under field condition. EM was further classified into earliest among early (EEM, 104-110 days), medium among early (MEM, 110-120 days) and late among early maturity (LEM, 120-130 days) groups. Different maturity groups of rice genotypes that exhibited significant correlation of environment components with SF and GY were subjected to combined and separate (with or without association of SF) regression analysis to determine the relation of important environment factors constituting variation in GY on high altitude.

Results and Discussion

The climatic condition remained favourable for normal growth and development of rice plants on hills during experimental period. An appreciable rainfall (1012.2 mm) was experienced during growing season and received 30.4, 48.5, 71.7, 362.3, 370.1, 124.3, 4.9 and 0.0 mm rains respectively from April to November. Maximum and minimum air temperature ranged between 23.9^0 - 11.8^0 in April and 17.5^0 - 5.6^0 C in November, respectively. Sensitivity of rice genotypes to cool environment brought about variation in maturity of reproductive phase transition. The differences in timing of reproductive phase transition had resulted in the rice genotypes exposed to variable climatic condition during mid season growth on high hills. During experimental period high rains coincided with flowering in most of the entries but two extreme maturity groups of rice cultivars, which fell apart of this critical situation. Among different maturity groups, LEM and MM genotypes had failed to establish significant relation between SF and GY (Table 1). The spikelet fertility (SF) and grain yield (GY) however, registered significant positive correlation with Rf_1 (0.688) and significant negative association with the differences in soil minimum temperature of ST_1 and ST_2 (-0.979) for MM and LEM genotypes, respectively at MS and PE stage of growth. Non-significant association of SF and GY with environment components made it difficult to classify MEM rice genotypes further into shorter range of maturity groups, which implied that no single explanation of cultivar events associated with tolerance. It was presumed that a complex photo-thermal interaction with rice genotypes during rainy season at growing site and/or physical separation between pollen grain and stigma at pollination during high rainfall possibly constituted this relation.

Influence of low temperature effect, in this investigation, appeared in two extreme maturity groups (EEM and LM) of rice genotypes at two different stage (MS-PE and PE-AN) of crop growth (Table 1) depending upon climatic condition on high hills. This suggested that sensitivity of rice to cool environment possibly associated with genotypic differences in maturity among rice plants. EEM experienced rain during grain filling period while LM was exposed to rain at pre-flowering stage. The correlation coefficient values indicated that soil minimum temperature at ST_1 (-0.619, -0.576) and ST_2 (-0.621, -0.578) exerted significant influence on SF and GY among EEM genotypes at PE-AN stage, contrarily differences in soil minimum temperature between ST_1 and ST_3 (0.463, 0.627), and soil maximum temperature at $ST_{1,}$ and ST_2 (-0.468, -0.566 and -0.499, -0.494, respectively) at MS-PE stage of growth registered significant relationship with SF and GY for LM genotypes. This indicated that variability in soil temperature and moisture availability in soil at critical stage would determine the efficiency of SF and GY potential of crop. Deficiency of moisture results from high soil temperatures and high irradiance of sun light on hills and affected the transport system of water supply by roots to fulfill the atmospheric demand possibly by changing root hydraulic conductivity. Alternatively it could be stated that an alteration in the capacity for phloem loading and long distance export of plants presumed to be a major limiting factor determining SF and GY of rice genotypes on hills. Early transition of reproductive phase before on set of monsoon, in this investigation, induced moisture deficit stress at critical stage of development for EEM genotypes on account of rise in soil temperature. Subsequent development of spikelets for fertilization, therefore, relies on efficient transport system for water and nutrients (Edmeades and Daynard, 1979) during the period of reduced water uptake. It was assumed that the factors which showed the ability to avoid dehydration or maintain metabolic processes despite dehydration (dehydration tolerance) are more likely to improve both SF and GY (Turner, 1979) among rice cultivars.

Correlation study revealed that more complex genotype x environment interaction was involved in grain production among LM genotypes. Earth surface holds good amount of soil moisture and remained cool after an immediate passage of monsoon during MS-PE stage of crop growth for late maturing rice (LM) genotypes. This indicated that despite genotypic differences in timing of reproductive primordial initiation at growing site, lack of development in cultivar- and stress factors- dependent mechanism of plant for efficient utilization of sucrose at an exposure to different levels of light intensity possibly associated with reduction in GY. It was, therefore, apparent that an increase in photosynthesis capacity (Savitha *et al*., 2000) at different levels of light (Allen and Ort, 2001; Sonoike, 1998) with an enrichment of greater light harvesting protein complex of PS II (Gesch and Heilman, 1999) for phosphorylation, permit an ecotype adapted to colder regions tolerated *in situ* condition of hills better than those ecotypes from warmer regions (Anderson and Mc Naughton, 1973). Barring the photosynthesis related physiology to the plants, the distribution of root in soil (Banba and Ohkuba, 1980), change in Root:Shoot ratio (Equiza *et al.*, 2001) and the capacity of osmotic adjustment (Long, 1974; Turner, 1986; Hsiao et al., 1984) of LM genotypes would be considered as potential measure to control plant water economy at sub-optimal temperature condition of hills because it allowed continuous growth of roots at lower water potential (Sharp and Davies, 1979) to overcome the response of water limitation and can substantially increase the volume of water available to the plant (Jordan *et al.*, 1983), while a consequent increase in fertility of spikelets and grain yield perhaps associated with the development of viable and engorged pollen grains, increasing the efficiency of interception by stigma, pollen germination and fertilization efficiency (Gunawardana *et al*., 2003).

Significant positive correlation of SW with differences in soil minimum temperature between ST_1 and ST_3 at an interval between MS and PE stage (0.570) and GY (0.513) indicated that carpel growth (weight) at pre-anthesis period may be critical for the determination of yield potential (Scott *et al*., 1983). It was presumed that the variation in soil minimum temperature between ST_1 and ST_3 at early floret development (MS-PE stage) possibly induced genotypic differences in size of reproductive organs of plants and the pre-fertilization genetic control of kernel weight, while the effect of ovary volume on kernel growth could operate via limitation imposed on kernel expansion capacity by developing pericarp derived from the ovary wall. This indicated that those environmental factors influencing water and assimilates availability are known to affect kernel weight. These results are in good agreement to that obtained by Yang et al. (2009) who attributed that after initiation of primodia final yield of crops depended upon pre-fertilization development of carpel from meristem. The importance of root distribution and the capacity of transport system of mother plant, to supply these resources into a kernel, appeared as major causal factors to induce significant differences among rice genotypes on hills. It was, therefore, apparent that the genetic and environmental factors that modify fertility and pre-fertilization development of ovary (carpel) possibly set a limit to final grain weight and yield (Calderini *et al*., 1999) of rice cultivars.

The study on regression analysis (Table 2) revealed differences in soil minimum temperature between ST_1 and ST_3 registered significant positive coefficient (b) values on GY in both combined and separate (with or without association of SF) analysis suggesting that on hills, differences in soil minimum temperature (between ST_1 and ST_3) had immense role on governing GY in LM genotypes while a possible alternative mechanism existed for maintaining spikelet fertility. It was, therefore, apparent that the diversity of symptoms of chilling injury at mid season stress in sensitive genotypes operates through intrinsic developmental process of plant growth. Extensive research showed that genotypic effects on meristem size, ovary volume and kernel weight were all consistent with additive genetic control, suggesting that they were causally related and an effective selection can make improvement of these traits. This study showed that rice genotypes adapted to hills exhibited greatest potential for cold tolerance and could be useful as a source for the improvement of rice genotypes tolerant to cold.

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Table 1: Correlation coefficient values among important plant traits and environment components (PT & EC) of rice genotypes on high hills under rain fed condition

Geno type	PT & EC	DP-MS	MS-PE	Air temperature and rain fall at MS-PE stage						Air temperature and -	
				Mxt	Mnt	Avt	Dut	RF_1	PE-AN	Mxt	Mnt
		1	2	3	4	5	6	7	8	9	10
T	SF	0.080	0.068	-0.036	-0.185	-0.114	0.032	0.171	0.000	0.169	-0.163
	GY	0.007	0.081	-0.002	-0.182	0.016	0.061	0.066	0.231*	-0.025	-0.105
EM	SF	-0.352*	-0.176	0.359*	-0.146	0.351*	0.307	0.409*	-0.071	0.192	-0.167
	GY	0.093	-0.014	-0.008	0.124	0.089	-0.055	0.106	0.206	-0.230	0.153
MM	SF	-0.334	0.270	-0.325	-0.190	-0.406	-0.193	0.688*	0.320	0.346	0.373
	GY	-0.339	-0.010	-0.358	-0.111	-0.393	-0.251	0.197	0.270	0.369	0.365
LM	SF	0.136	0.117	-0.298	-0.153	-0.132	-0.141	0.308	0.117	0.134	-0.147
	GY	0.574*	0.783**	-0.379	-0.615	-0.086	0.319	-0.141	0.308	0.295	-0.492*
EEM	SF	0.057	-0.347	-0.189	0.180	0.258	-0.208	-0.313	0.234	-0.594*	0.548
	GY	0.040	-0.325	-0.154	-0.067	0.269	-0.193	-0.143	0.255	-0.542	0.475
MEM	SF	-0.349	-0.108	0.622**	-0.117	0.606**	0.582*	0.398	-0.155	0.237	-0.542*
	GY	0.102	0.138	0.089	-0.040	0.057	0.099	0.144	0.237	-0.186	0.022
LEM	SF	-0.025	-0.130	0.114	0.138	0.103	0.135	0.776	-0.032	-0.217	0.866
	GY	-0.218	0.213	0.271	-0.045	0.265	0.301	0.803	0.399	-0.129	0.591
EEM_1	RF_1	-0.443	0.934**	0.678*		-0.766**	0.735**	1.000	0.100	0.710	-0.532
LM		-0.593*	0.278	-0.405	0.439	-0.350	-0.945**	1.000	-0.285	-0.195	0.321
EEM_2	RF_2	-0.449	-0.036	0.333		-0.310	0.328	-0.129	0.877**	-0.628*	0.755**
LM		-0.573*	-0.469	0.892**	0.712**	0.265	0.110	-0.246	-0.607*	-0.149	0.799**
EEM	SW	-0.346	0.138	0.322		-0.292	0.323	0.066	0.059	0.424	-0.132
LM		0.461	0.025	0.193	0.429	0.442	0.711**	-0.527*	0.232	0.425	-0.188

		rain fall at PE-AN stage			Soil minimum temperature at MS-PE stage						Soil
		Avt	Dut	RF_2	ST_1	ST_2	ST_3	ST_1-ST_2	ST_2-ST_3	ST_1-ST_3	ST_1
		11	12	13	14	15	16	17	18	19	20
T	SF	-0.013	0.260*	-0.325*	-0.117	-0.162	-0.211	0.071	-0.149	-0.074	-0.057
	GY	-0.094	0.063	0.008	-0.040	-0.051	-0.020	0.023	-0.007	0.016	-0.096
EM	SF	0.138	0.233	-0.345*	0.042	-0.058	-0.227	0.067	-0.389*	-0.247	0.265
	GY	-0.237	-0.221	0.205	0.087	0.050	0.180	-0.154	-0.012	-0.103	-0.232
MM	SF	0.357	0.287	0.148	0.415	0.367	0.373	-0.515	0.373	0.275	0.328
	GY	0.369	0.354	0.019	0.293	0.276	0.299	-0.266	0.322	0.283	0.319
LM	SF	-0.055	0.185	-0.366	-0.253	-0.222	-0.177	0.298	0.376	0.463*	-0.034
	GY	-0.235	0.549*	-0.512*	-0.698**	-0.645**	-0.606*	0.705**	0.084	0.627**	-0.344
EEM	SF	-0.110	-0.519	0.327	-0.162	0.236	-0.138	-0.217	-0.233	-0.238	-0.619*
	GY	-0.026	-0.429	0.353	0.067	0.135	-0.185	-0.143	-0.239	-0.229	-0.576*
MEM	SF	-0.218	0.258	-0.276	0.237	-0.042	-0.104	0.053	-0.392	-0.395	0.270
	GY	-0.055	-0.177	0.265	0.183	-0.147	0.064	-0.092	0.099	0.092	-0.203
LEM	SF	0.180	-0.177	-0.161	-0.124	-0.058	0.235	-0.880	-0.285	-0.674	-0.599
	GY	-0.012	-0.124	0.079	-0.045	0.050	-0.210	-0.979*	-0.496	-0.870	-0.388
EEM_1	RF_1		0.588	-0.129				0.762**	0.786**	0.797**	0.624*
LM		0.133	0.382	-0.246	0.334	0.320	0.363	-0.484	0.433	-0.116	0.384
EEM_2	RF_2		-0.726*	1.000				0.306	0.283	0.285	-0.786

											**
LM		0.571*	-0.702**	1.000	0.772**	0.790**	0.768**	-0.448	0.045	-0.263	0.658**
EEM	SW		0.423	-0.182				0.384	0.311	0.302	0.347
LM		0.117	0.385	-0.034	-0.430	-0.400	-0.370	0.658**	0.013	0.570*	-0.074

		Minimum temperature at PE-AN stage					Soil maximum temperature at MS-PE				
		ST_2	ST_3	ST_1-ST_2	ST_2-ST_3	ST_1-ST_3	ST_1	ST_2	ST_3	ST_1-ST_2	ST_2-ST_3
		21	22	23	24	25	26	27	28	29	30
T	SF	-0.026	0.005	0.188	0.171	0.226	-0.171	-0.159	-0.186	-0.134	-0.086
	GY	-0.085	-0.054	0.094	0.142	0.147	0.103	0.099	0.051	0.177	0.187
EM	SF	0.276	0.294	0.114	0.319*	0.306	-0.273	-0.243	-0.274	-0.311*	-0.165
	GY	-0.209	-0.204	-0.237	-0.159	-0.173	0.188	0.200	0.183	0.161	0.229
MM	SF	0.365	0.355	0.081	0.184	0.114	0.382	0.361	0.379	0.409	0.314
	GY	0.357	0.359	0.034	0.290	0.162	0.294	0.266	0.283	0.326	0.229
LM	SF	-0.048	0.000	0.036	0.142	0.090	-0.468*	-0.499*	-0.319	0.194	-0.255
	GY	-0.307	-0.218	0.402	0.480*	0.438	-0.566*	-0.494*	-0.609*	0.175	0.231
EEM	SF	-0.621*	-0.190	-0.001	-0.201	-0.121	0.081	0.235	-0.162	0.160	0.230
	GY	-0.578*	0.138	0.001	-0.249	-0.124	0.055	0.242	0.087	0.143	0.334
MEM	SF	0.282	-0.235	0.131	0.310	0.301	-0.240	-0.225	0.215	-0.247	-0.183
	GY	-0.169	0.016	-0.248	-0.173	-0.193	0.157	0.164	-0.013	0.178	0.176
LEM	SF	-0.433	0.221	-0.238	-0.163	-0.028	0.101	0.063	-0.146	0.248	0.068
	GY	-0.233	-0.032	-0.070	0.006	-0.040	0.223	0.198	-0.094	0.323	0.225
EEM_1	RF_1	0.627*		0.037	-0.189	-0.185	-0.163	-0.600		-0.660*	-0.570
LM		0.289	0.235	-0.538	-0.428	-0.489	-0.319	-0.490	0.016	0.123	-0.870**

EEM_2	RF_2	0.789**		-0.001	-0.656*	-0.606*	-0.204	-0.344		0.081	-0.297
LM		0.645*	0.547*	-0.518*	-0.665**	-0.586*	0.908**	0.865**	0.920**	-0.350	-0.176
EEM	SW	0.348		-0.001	-0.144	-0.235	0.109	-0.441		0.136	-0.303
LM		0.001	0.093	0.339	0.341	0.344	-0.147	-0.046	-0.241	-0.201	0.333

		stage	Soil maximum temperature at PE-AN stage						FG	NS	SW
		ST_1-ST_3	ST_1	ST_2	ST_3	ST_1-ST_2	ST_2-ST_3	ST_1-ST_3			
		31	32	33	34	35	36	37	38	39	40
T	SF	-0.123	0.174	0.179	0.132	0.157	0.280*	0.201	0.826**	0.164	-0.464**
	GY	0.189	0.060	0.041	0.038	0.068	0.093	0.061	0.495**	0.267*	-0.152
EM	SF	-0.268	0.360*	0.353*	0.338*	0.366*	0.376*	0.372*	0.818**	0.281	-0.437*
	GY	0.189	-0.142	-0.172	-0.182	-0.153	-0.152	-0.152	0.580**	0.350*	-0.413*
MM	SF	0.388	0.093	0.099	0.210	0.086	-0.152	-0.031	0.882**	-0.178	-0.619
	GY	0.315	0.134	0.140	0.243	0.126	-0.110	0.015	0.209	-0.539	-0.092
LM	SF	0.036	0.341	0.371	0.417	0.283	0.378	0.295	0.847**	0.554*	0.180
	GY	0.236	0.563*	0.566*	0.592*	0.546*	0.620*	0.535*	0.612*	0.543*	0.513*
EEM	SF	0.257	-0.399	-0.456	-0.483	-0.296	-0.410	-0.334	0.706*	0.509	-0.281
	GY	0.264	-0.412	-0.460	-0.486	-0.324	-0.425	-0.357	0.618*	0.502	-0.240
MEM	SF	-0.242	0.327	0.322	0.312	0.333	0.340	0.337	0.862**	0.109	-0.597**
	GY	0.154	-0.167	-0.168	-0.169	-0.166	-0.165	-0.165	0.604**	0.307	-0.492

											*
LEM	SF	0.159	0.185	0.121	-0.028	0.483	0.346	0.423	0.882	0.496	-0.964*
	GY	0.279	0.134	0.087	0.001	0.377	0.209	0.290	0.917	0.630	-0.837
EEM_1	RF_1	-0.816	0.088	0.184	0.227	-0.063	0.091	-0.012	-0.141	-0.075	0.066
LM		-0.257	-0.039	0.030	0.112	-0.158	-0.106	-0.115	0.224	0.133	-0.527*
EEM_2	RF_2	-0.262	-0.817**	-0.854**	-0.867**	-0.734*	-0.823**	-0.765**	0.065	-0.011	-0.182
LM		-0.354	-0.930**	-0.948**	-0.954**	-0.875**	-0.875**	-0.898**	-0.395	-0.323	-0.034
EEM	SW	-0.291	-0.005	0.054	0.083	-0.093	0.011	-0.065	-0.157	-0.028	1.000
LM		-0.016	0.203	0.187	0.201	0.234	0.303	0.199	0.136	0.048	1.000

		l;b ratio	SF	GY							
		41	42	43							
T	SF	-0.278	1.000	-							
	GY	-0.189	0.450**	1.000							
EM	SF	-0.288	1.000	-							
	GY	-0.346*	0.515*	1.000							
MM	SF	-0.448	1.000	-							
	GY	0.320	0.513	1.000							
LM	SF	-0.189	1.000	-							
	GY	-0.195	0.497*	1.000							
EEM	SF	-0.555	1.000	-							
	GY	-0.374	0.592*	1.000							
MEM	SF	-0.013	1.000	-							

	GY	-0.244	0.494*	1.000							
LEM	SF	-0.778	1.000	-							
	GY	-0.845	0.904	1.000							
EEM_1	RF_1	0.101	-0.313	-0.143							
LM		0.137	0.308	-0.141							
EEM_2	RF_2	-0.429	0.327	0.353							
LM		-0.077	-0.366	-0.512							
EEM	SW	0.248	-0.281	-0.240							
LM		0.051	0.180	0.513*							

**, * significant at 1 and 5 percent level of probability

t value for testing the significance of correlation between two variables changed with change in number of genotypes represent respective maturity group of rice

T = Entire rice genotypes (combining all maturity groups); EM = Early maturity group; MM = Medium maturity group; LM = Late maturity group; EEM = Earliest among early maturity group; MEM = Medium among early maturity group; LEM = Late among early maturity group; DP-MS = Time interval between date of planting seeds on field to microspore development stage (Days); MS-PE= Time interval between microspore development stage to date of panicle emergenceon plant on main shoot (Days); Mxt = Maximum air temperature, Mnt = Minimum air temperature; Avt = Average air temperature; Dut = Diurnal variation in air temperature; RF_1 = Rain fall experience during the time interval of DP-MS stage; PE-AN =Time interval between panicle emergence to date of anthesis (Days); RF_2 = Rain fall experienced between the time interval of PE-AN stage; ST_1 = Soil temperature at 5 cm depth; ST_2 = Soil temperature at 10 cm depth; ST_3 = Soil temperature at 20 cm depth; ST_1-ST_2 = Differences in soil temperature between ST_1 and ST_2 depth; ST_2-ST_3 = Differences in soil temperature between ST_2 and ST_3 depth; ST_1-ST_3 = Differences in soil temperature between ST_1 and ST_3 depth. DP = Date of planting the seeds on field, MS = Microspore development stage, PE = Panicle emergence stage, AN = Anthesis stage FG = Percent of filled grain, NS = Total number of spikelet present on a panicle, SW = 100 seed weight, SF = Percent of spikelet fertility, l;b = Length : breadth ratio of seed. GY = Grain yield.

Table 2: Regression equations in separate (soil component on spikelet fertility and grain yield) and combined (soil component in association with spikelet fertility on grain yield) analysis.

Late maturing rice genotypes (LM) :- $GY = - 132.6092 + 2.85046 X_1$ ($R^2 = 0.247294$)

$SF = - 98.6874 + 107.7920 X_2$	$GY = - 1233.00 + 836.5570^* X_2$	$GY = - 1084.05 + 673.8685^* X_2 + 1.5092 X_1$
($R^2 = 0.2145$)	($R^2 = 0.3932$)	($R^2 = 0.4477$)
$SF = 605.3604 - 19.2762 X_3$	$GY = 3783.834 - 133.5551^* X_3$	$GY = 2754.64 - 100.7828 X_3 + 1.7000 X_1$
($R^2 = 0.2200$)	($R^2 = 0.3214$)	($R^2 = 0.3900$)
$SF = 37.5135 - 26.1189 {}^*X_4$	$GY = 3857.981 - 148.1273 X_4$	$GY = 2446.962 – 98.1579 X_4 + 1.9132 X_1$
($R^2 = 0.2493$)	($R^2 = 0.2441$)	($R^2 = 0.3277$)

Earliest among early maturing genotypes (EEM) :- $GY = - 106.4013 + 2.581240^* X_1$ ($R^2 = 0.350628$)

$SF = 1378.531 - 63.3133^* X_5$	$GY = 5388.635 - 256.7548 X_5$	$GY = 3086.405 - 151.0177 X_5 + 1.67002 X_1$
($R^2 = 0.3817$)	($R^2 = 0.3303$)	($R^2 = 0.4210$)
$SF = 1401 - 61.7472^* X_6$	$GY = 5874.274 - 268.5456^* X_6$	$GY = 3718.013 - 173.5408 X_6 + 1.5386 X_1$
($R^2 = 0.3707$)	($R^2 = 0.3689$)	($R^2 = 0.4473$)

X_1 = Spikelet of fertility; X_2 = Differences in soil minimum temperature between ST_1 and ST_3 depth at MS-PE stage; X_3 = Soil maximum temperature at ST_1 depth at MS-PE stage; X_4 = Soil maximum temperature at ST_2 depth at MS-PE stage; X_5= Soil maximum temperature at ST_1 depth at PE-AN stage; X_6= Soil maximum temperature at ST_2 depth at PE-AN stage

Abbreviations

T = Entire rice genotypes (combining all maturity groups); EM = Early maturity group; MM = Medium maturity group; LM = Late maturity group; EEM = Earliest among early maturity group; MEM = Medium among early maturity group; LEM = Late among early maturity group; DP-MS = Time interval between date of planting seeds on field to microspore development stage (Days); MS-PE= Time interval between microspore development stage to date of panicle emergence on main shoot plant (Days); Mxt = Maximum air temperature, Mnt = Minimum air temperature; Avt = Average air temperature; Dut = Diurnal variation in air temperature; RF_1 = Rainfall experience during the time interval of DP-MS stage; PE-AN =Time interval between panicle emergence to date of anthesis (Days); RF_2 = Rain fall experienced between the time interval of PE-AN stage; ST_1 = Soil temperature at 5 cm depth; ST_2 = Soil temperature at 10 cm depth; ST_3 = Soil temperature at 20 cm depth; ST_1-ST_2 = Differences in soil temperature between ST_1 and ST_2; ST_2-ST_3 = Differences in soil temperature between ST_2 and ST_3; ST_1-ST_3 = Differences in soil temperature between ST_1 and ST_3. DP = Date of planting the seeds in the field, MS = Microspore development stage, PE = Panicle emergence stage, AN = Anthesis stage, FG = Percent of filled grain, NS = Total number of spikelet present on a panicle, SW = 100 seed weight, SF = Percent of spikelet fertility, 1:b = Length : breadth ratio of seed. GY = Grain yield.

Production Potential of Rice (*Oryza Sativa L.*) Varieties under Different Nitrogen Levels

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Abstract

Production potential of rice varieties under different nitrogen levels was studied for four consecutive seasons i.e., *kharif* 2007 and 2008 and *rabi* seasons of 2007 and 2008 at Jagtial. Results revealed that during *Kharif* 2007, varieties JGL-1798, JGL-11470 and JGL-3855 were equally superior in terms of grain and straw yields and nitrogen uptake. During *kharif* 2008, varieties JGL-11470 and JGL-3855 recorded significantly superior grain, straw yield and N uptake over other varieties tested. During *rabi* 2007-08, variety JGL-3855 recorded significantly superior grain yield and nitrogen uptake over other varieties. While during 2008-09 *rabi*, there were no significant differences in grain and straw yields and N uptake among varieties. The response to applied nitrogen was observed up to 100 % RDN (100 kg N ha^{-1}) during *Kharif* 2008 and up to 150% RDN (180 kg N ha^{-1}) during *rabi* seasons of 2007-08 and 2008-09, respectively. Soil available nitrogen status was significant only during *rabi* 2008-09. Lower soil nitrogen values were recorded in plots fertilized with 150% RDN.

Key words: Rice varieties, nitrogen levels, yield and nitrogen uptake.

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Rice (*Oryza sativa* L.) is the principal cereal crop of India and world. Andhra Pradesh is considered as rice granary and enjoys a pride place among rice growing states of India. With ever increasing population, demand for rice will continue to increase. In this endeavour, in addition to high yielding rice varieties, efficient use of nutrients play an important role. Among the major plant nutrients, nitrogen is most important for augmenting rice yield. Rice is the major consumer of fertilizer nitrogen and accounts for one third of the total nitrogen consumption in the country.

Application of optimum dose of nitrogen to rice is gaining importance because nitrogen is a key nutrient in crop production that it can never be ignored. It is crucial for individual farmer as well as to the country to get the maximum economic benefit out of a huge recurring expenditure.

Identification and use of high yielding potential cultivars, though ensures higher yields, the actual yield advantage depends on the agronomic management including that of nitrogen management. Yield potential of a cultivar could be exploited to a maximum extent by judicious management of applied nitrogen.

As nitrogen deficiency is universal, significant yield increase due to nitrogen use is common. In general, about 10-12 kg of rice is obtained per every kg of applied nitrogen. Magnitude of response varies with season, soil characteristics, variety and cultural practices (Pillai *et al*., 1976).

Identification of location specific cultivar and optimum nitrogen dose are essential for increasing the productivity of rice. Such information is lacking for the newly developed rice cultivars *viz;* JGL 1798, JGL 3844, JGL 3855 and JGL 11470 under Northern Telangana region during *kharif* and *rabi* seasons. Keeping these points in view, the present investigation was initiated during *kharif* and *rabi* seasons on sandy clay soils of Jagtial.

Material and Methods

Field experiments were carried out for four consecutive seasons of k*harif* 2007 and 2008 and *rabi* 2007 and 2008 at Regional Agricultural Research Station, Jagtial, Karimnagar, Acharya N.G. Ranga Agricultural University, Andhra Pradesh. The soil of the experimental site was sandy clay in texture, low in organic carbon (0.42%) and available nitrogen (198 kg ha^{-1}) medium in available phosphorus (18.6 kg ha^{-1}) and high in available potassium (384 kg ha^{-1}). The treatments consisted of four rice varieties *viz*., JGL 1798, JGL 3844, JGL 3855 and JGL 11470 and four nitrogen levels 100% RDN (RDN-100 kg N ha^{-1} during *kharif* and 120 kg N ha^{-1} during *rabi*) 125, 150 and 175% RDN, The experiment was laid out in randomized block design with factorial replicated thrice. Seedlings of 30 days old were transplanted at 15 cm x 15 cm spacing @ two seedlings per hill. Nitrogen (Urea) was applied as per treatments in three equal splits (1/3 as basal, 1/3 at maximum tillering and 1/3 at panicle initiation stage). Phosphorus (50 and 60 kg ha^{-1}) and potassium (40 kg ha^{-1}) were supplied through single super phosphate and muriate of potash and were uniformly applied to all plots as basal during *kharif* and *rabi* seasons. Recommended agronomic practices and plant protection measures were followed. Concentration (%) of N was estimated in plant samples as per Jackson (1973). The uptake of nitrogen (N) was calculated as a product of concentration and total biomass.

Results and Discussion

Grain Yield

Effect of varieties

It is evident from the data (Table 1) that during *kharif* 2007, among the rice varieties tested, JGL-1798 recorded significantly higher grain yield (7102 kg ha^{-1}) over JGL-3844 (6052 kg ha^{-1}) and was statistically comparable with JGL-11470 and JGL-3855.

During *Kharif* 2008, varieties JGL-11470 and JGL-3855 recorded significantly superior grain yield over rest of the varieties tested. Similar to *Kharif* 2007, variety JGL-3844 recorded significantly lower yield (6182 kg ha^{-1}) over rest of the varieties.

During *rabi* 2007-08, JGL-3855 out yielded (7054 kg ha^{-1}) other varieties and was significantly superior to rest of the varieties tested. The varieties JGL-11470, JGL-3844 and JGL-1798 were at par with each other in terms of grain yield. However, during *rabi* 2008-09, there were no significant differences among varieties in terms of grain yield.

The variation in grain yield among different varieties was due to the differential efficiency of these varieties in converting dry matter into grain. Similar findings were also reported regarding varietal performance under different nitrogen levels in rice by Priydarshini and Prasad (2003) and Srilaxmi *et al*. (2005).

Effect of Nitrogen levels

Among the nitrogen levels tested, there was no significant improvement in grain yield due to incremental N application over 100% RDN during *Kharif* season of 2007. During *Kharif* 2008, linear and significant increase in grain yield was recorded with 175% RDN over 100% RDN. However, the grain yield at 175, 150 and 125% RDN was comparable to each other (Table 1).

During *rabi* 2007-08 and 2008-09, crop applied with 175% RDN recorded significantly higher grain yield over 100, 125% RDN but was comparable to 150% RDN. The increase in grain yield due to 175% RDN was to a tune of 8.0 and 10.0 % over 100% RDN during *rabi* 2007-08 and 2008-09.

Application of higher level of nitrogen might have helped in the maintenance of optimum nutrient level in the plant, enabling quick establishment with good root development. Thus, wider spread of roots, might have resulted in absorption of more amount of nutrients due to greater exploration from the soil as evident from the nutrient uptake data (Table 2). Further, adequate nutrient availability might have resulted in enhanced amount of protoplasm and chlorophyll which play vital role in increased assimilation of photosynthates, dry matter production, number of productive tillers which finally reflected in higher grain yields (Singh *et al*., 2000). During *rabi*, the response to higher nitrogen level was due to the favourable weather conditions (bright sunshine hours) coupled with improved nutrient availability due to minimal losses under controlled irrigation over *kharif* season (Kavitha *et al*., 2009).

The interaction effect of varieties and nitrogen levels on grain yield was found to be non-significant during both the seasons and years.

Straw Yield
Effect of varieties

During *kharif* 2008, varieties JGL-3855, JGL-11470 and JGL-1798 recorded significantly higher straw yield over JGL-3844 and were comparable which each other in terms of straw yield. However, during *Kharif* 2009, varieties JGL–11470 and JGL-3855 were at par with each other and were significantly superior over JGL – 1798 and JGL-3844 in terms of straw yield. The varieties JGL–1798 and JGL-3844 recorded comparable straw yield.

Effect of Nitrogen levels

Application of higher level of nitrogen over 100% RDN had no significant effect on straw yield during *kharif* 2008 and r*abi* 2007 –08 and 2008 –09, respectively.

The interaction effect of varieties and nitrogen levels on straw yield was found to be non significant during both the seasons and years.

Nitrogen Uptake

Effect of varieties

Similar to the grain yield, variety JGL-11470 recorded significantly higher total N uptake and was comparable to varieties JGL-3855 and JGL-1798 in terms of N uptake. Lowest N uptake was recorded with JGL-3844 (92 kg ha^{-1}) during *kharif*, 2007. During *Kharif* 2008, JGL-3855 and JGL-11470 recorded significantly higher N uptake over other rice varieties tested.

During *rabi* 2007-08 highest nitrogen uptake (86 kg ha^{-1}) was recorded with JGL-11470, while JGL-3855 accumulated significantly lower nitrogen (64 kg ha^{-1}) over rest of the varieties tested. However, during *rabi* 2008-09, similar to the grain yield, there were no significant differences among different varieties in terms of total N uptake.

Effect of N levels

During *kharif* 2007, there were no significant differences in total N uptake due to increased application of N over 100% RDN. During *kharif* 2008, there was linear increase in N uptake with each increase in N level above 100% RDN. However, N uptake at 125, 150 and 175% RDN was comparable with each other.

During *rabi* 2007-08, application of 175% RDN recorded significantly higher N uptake over 100, 125 and 150% RDN while lowest N uptake was observed in crop fertilized with 100% RDN. However, during *rabi* 2008-09, there were no significant differences in N uptake due to different N levels.

The interaction effect of varieties and nitrogen levels on N uptake by crop was found to be non significant during both the seasons and years.

Application of nitrogen increases the root cation exchange capacity and root surface area which enhance nitrogen absorption. Further, increased absorption of N increases leaf area and ultimately results in increased biomass production (Neelima and Bhanu Murthy, 2009). Nutrient uptake is the product of nutrient content and dry matter production and increased N uptake by crop at higher levels of N (Table 3) might be due to increased grain and straw yields as evident from Table 1 and 2.

The interaction effect due to varieties and N levels was found to be non-significant on Nitrogen uptake.

Post Harvest Soil Nitrogen Status

A perusal of data (Table 4) indicated that there were no significant differences in post harvest soil available N status during wet seasons of 2007, 2008 and *rabi* 2007-08.

However, during *rabi* 2008-09, the soil available N status was significantly lower in plots applied with 150 % RDN. The available soil N status in plots supplied with 100, 125 and 175% RDN was significantly higher over 150% RDN and was comparable with each other. Lower values associated with this treatment were due to higher grain and straw yield recorded as evident from Table 1 and 2. The variation in soil available N status was due to the variation in N uptake by crop under different N levels coupled with low initial soil N status. The effect of different rice varieties and the interaction effect of varieties and N levels was found to be non-significant on available soil N status.

Conclusion

The results indicated that under Northern Telangana Zone, varieties JGL-3855 and JGL-11470 recorded significantly superior grain and straw yields and higher total N uptake during *kharif* season and application of 100% RDN (100 kg N ha^{-1}) was optimum during this season for realizing profitable yields. During *rabi* season, variety JGL – 3855 out yielded other varieties and the response in terms of grain yield was observed up to 150% RDN (180 kg N ha^{-1}).

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Table 1: Grain and straw yield (kg ha^{-1}) of different rice varieties as influenced by nitrogen levels

	Grain yield				**Straw yield**			
	Kharif		***Rabi***		***Kharif***		***Rabi***	
	2007	**2008**	**2007-08**	**2008-09**	**2007**	**2008**	**2007-08**	**2008-09**
Variety								
JGL 1798	7102	6442	6708	6883	6568	5942	6670	5509
JGL 3844	6052	6182	6760	6700	5952	5781	6679	5570
JGL 3855	6821	6630	7054	6618	6913	6371	7010	5400
JGL 11470	6965	6678	6798	6949	6875	6454	6716	5658
CD (0.05)	**435**	**221**	**255**	**NS**	**410**	**341**	**NS**	**NS**
N level								
100 % RDN	6696	6321	6530	6437	6495	5700	6623	5291

125 % RDN	6802	6450	6803	6779	6561	6007	6705	5478
150% RDN	6799	6520	7094	7083	6591	6423	6983	5791
175% RDN	6643	6643	6894	6851	6660	6418	6764	5571
CD (0.05)	**NS**	**221**	**255**	**402**	**NS**	**341**	**NS**	**NS**

Table 2: Nitrogen uptake (kg ha^{-1}) by different rice varieties as influenced by nitrogen levels

Nitrogen uptake (kg ha^{-1})				
	Kharif		***Rabi***	
	2007	**2008**	**2007-08**	**2008-09**
Variety				
JGL 1798	100	95	75	99
JGL 3844	92	98	74	93
JGL 3855	107	110	64	96
JGL 11470	112	105	86	94
CD (0.05)	**14**	**9**	**6**	**NS**
100 % RDN	100	95	70	91
125 % RDN	105	100	82	96
150% RDN	110	106	90	101
175% RDN	95	107	102	94
CD (0.05)	**NS**	**9**	**6**	**NS**

Table 3: Post harvest soil nitrogen status (kg ha^{-1}) under different nitrogen levels

	Kharif		***Rabi***	
	2007	**2008**	**2007-08**	**2008-09**
100 % RDN	91	101	104	197
125 % RDN	94	100	104	193
150% RDN	93	101	97	164
175% RDN	91	101	105	171
CD (0.05)	**NS**	**NS**	**NS**	**26**

Effect of Age of Seedlings and Weed Management Practices on Certain Growth Parameters of Rice under System of Rice Intensification (SRI)

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Abstract

During Thaladi and Kuruvai seasons in 2009 to 2010, two field experiments were carried out at Annamalai University Experimental Farm in a factorial randomized block design with three replications. The treatments were formed by combination of two age of seedlings and four weed management practices that were tested on SRI crop. All the treatments and their combinations significantly influenced the growth aspects. Conoweeding four times adopted in 15 days old rice seedlings ranked first and resulted in increased plant height, LAI, tillers m^{-2} and DMP over unweeded control. The next best was butachlor application @ 1.5 kg a.i. ha^{-1} + hand weeding and both were comparable.

Key Words: System of rice intensification, age of seedlings, weed management.

Rice is a staple food for more than half of the global population and it is a predominant crop in lowland ecosystem. Tamil Nadu is one of the important rice growing states in India wherein rice is cultivated on 1.93 m ha with a production of 5.18 m t and the productivity is 2.68 t ha^{-1} which is very low when compared to world average of 4.25 t ha^{-1} . Rice contributes 20 to 25 per cent of agricultural GDP in India and its production has to be necessarily increased in India to meet the growing population and that too with reduced available irrigation water. System of Rice Intensification (SRI) is one of the ways to solve the water crisis in rice cultivation and to increase the rice yield three to four times as compared to conventional farmer's cultivation (Uphoff, 2002).

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Materials and Methods

To evaluate the effect of age of seedlings and weed management practices on certain growth parameters of rice under SRI, two field experiments were conducted at Annamalai University Experimental Farm which is located at 11°24' North latitude, 79°44' East longitude and at an altitude of 5.79 m above mean sea level. The experimental soil is clay loam in texture with a pH of 8.4. The soil is low in available nitrogen (227 kg ha^{-1}), medium in available (17 kg ha^{-1}) phosphorus and in available potassium high (346 kg ha^{-1}). The experiments were conducted during Thaladi (August 2009 to January 2010) and Kuruvai seasons (June 2010 to September 2010) with Co 43 and ADT 43 cultivars, respectively. The experiments were conducted in a factorial randomized block design with treatments formed by combination of two age of seedling (M_1 – 10 days old seedlings and M_2 - 15 days old seedlings) and four weed management practices (S_1 – conoweeding two times at 10 and 20 DAT, S_2 – conoweeding four times at 10, 20, 30 and 40 DAT, S_3 – pre-emergence application of butachlor @ 1.5 kg a.i. ha^{-1} on 3 DAT + hand weeding on 35 DAT and S_4 – unweeded control). Butachlor was applied to respective plots by mixing it with sand @ 50 kg ha^{-1}. Standard package of practices were adopted for both the crops. Plant height, number of tillers m^{-2} and crop dry matter production were recorded at harvest. Leaf area index (LAI) was computed at active tillering stage by using the formula suggested by Yoshida *et al*. (1976).

Results and Discussion

Age of Seedlings

Significant influence of age of seedlings was observed during both the seasons. Transplanting of 15 days old seedlings resulted in the tallest plants (Table 1), more number of tillers m^{-2} (Table 2) higher LAI (Table 3), and higher dry matter production (DMP) (Table 4) in both the seasons compared to 10 days old seedlings. This observation was confirmed by the earlier findings of Tao *et al*. (2002).

Weed management practices

All the weed management practices exerted significant influence on growth parameters of rice. Within the weed management practices, conoweeding four times increased the plant height (23.85 and 21.25 cm) (Table 1), LAI (2.27 and 3.11) (Table 2), tillers m^{-2} (181.62 and 170.79) (Table 3) and DMP (6.49 and 6.18 t ha^{-1}) (Table 4) over unweeded control in Thaladi and Kuruvai seasons, respectively and was on par with butachlor application @ 1.5 kg a.i. ha^{-1} + hand weeding on 35 DAT. Least growth parameters were registered in unweeded control in both the seasons.

Interaction effect

The interaction between the age of seedlings and weed management practices was marked on the growth parameters during both the seasons. Transplanting of 15 days old seedlings coupled with conoweeding four times resulted in taller plants (116.2 and 109.0 cm), the higher number of tillers m^{-2} (459.6 and 434.3), LAI (6.43 and 5.64), and DMP (14.65 and 14.20 t ha^{-1}) in Thaladi and Kuruvai seasons, respectively. However, it was comparable with butachlor application @ 1.5 kg a.i. ha^{-1} + hand weeding on 35 DAT. The least growth parameters were observed in unweeded control. All the weed management practices exerted similar effect when they practiced in 10 days old seedlings. The increased growth parameters in 15 days old seedlings plus conoweeding four times might be due to lesser competition from weeds, vigour of seedlings, wider spacing, presence of thin film of water, improved respiration of roots, root development, absence of mutual shading and increased uptake of nutrients (Uphoff, 2001; Thiyagarajan *et al*., 2002; Natesan *et al*., 2008).

It may be concluded that in SRI, transplanting of 15 days old seedlings coupled with conoweeding four times at 10, 20, 30 and 40 DAT favourably increased the growth parameter which ultimately reflected in higher yield.

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Table 1: Plant height (cm) at harvest stage

	Thaladi crop Co-43			Kuruvai crop ADT-43		
Age of seedlings (M) / Weed management practices (S)	**M_1**	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	102.0	105.2	103.6	96.3	100.2	98.2
S_2	112.5	116.2	114.4	105.50	109.0	107.3
S_3	110.7	114.4	112.5	103.8	107.3	105.5
S_4	88.5	92.5	90.5	83.9	88.1	86.0
Mean	103.4	107.1	105.3	97.4	101.1	99.3
	M	S	M x S	M	S	M x S
SEd±	0.79	0.84	1.67	0.74	0.80	1.60
CD (p=0.05)	**1.71**	**1.81**	**3.61**	**1.61**	**1.73**	**3.46**

Table 2: Number of tillers m^{-2} at maximum tillering stage

	Thaladi crop Co-43			Kuruvai crop ADT-43		
Age of seedlings (M) / Weed management practices (S)	**M_1**	**M_2**	**Mean**	**M_1**	**M_2**	**Mean**
S_1	372	396	384	352	375	364
S_2	436	460	448	412	434	423

S_3	420	443	431	397	419	408
S_4	251	281	266	241	264	252
Mean	370	395	382	351	373	362
	M	S	M x S	M	S	M x S
SEd±	5.71	7.68	10.84	5.09	7.03	10.09
CD (p=0.05)	**12.27**	**16.51**	**23.31**	**10.94**	**15.11**	**21.90**

Table 3: Leaf area index at maximum tillering stage

	Thaladi crop Co-43			**Kuruvai crop ADT-43**		
Age of seedlings (M) / **Weed management practices (S)**	$\mathbf{M_1}$	$\mathbf{M_2}$	**Mean**	$\mathbf{M_1}$	$\mathbf{M_2}$	**Mean**
S_1	4.66	5.22	4.94	3.99	4.39	4.19
S_2	5.89	6.43	6.16	5.12	5.64	5.38
S_3	5.58	6.12	5.85	4.82	5.34	5.08
S_4	3.57	4.21	3.89	2.02	2.53	2.27
Mean	4.92	5.49	5.20	3.98	4.47	4.23
	M	S	M x S	M	S	M x S
SEd±	0.10	0.14	0.20	0.09	0.14	0.19
CD (p=0.05)	**0.22**	**0.31**	**0.44**	**0.21**	**0.30**	**0.42**

Table 4: Crop dry matter production (t ha^{-1}) at harvest stage

	Thaladi crop Co-43			**Kuruvai crop ADT-43**		
Age of seedlings (M) / **Weed management practices (S)**	$\mathbf{M_1}$	$\mathbf{M_2}$	**Mean**	$\mathbf{M_1}$	$\mathbf{M_2}$	**Mean**
S_1	9.53	10.57	10.05	9.33	10.28	9.80
S_2	12.53	14.65	13.59	12.00	14.20	13.10
S_3	11.37	13.49	12.43	11.05	13.25	12.15
S_4	6.11	8.10	7.10	6.05	7.80	6.92
Mean	9.88	11.70	10.79	9.60	11.38	10.49
	M	S	M x S	M	S	M x S
SEd±	0.40	0.52	0.90	0.28	0.43	0.80
CD (p=0.05)	**0.89**	**1.16**	**1.96**	**0.64**	**0.95**	**1.73**

Effect of Integrated Nutrient Management (INM) on Humic substances and Micronutrient Status in Submerged Rice Soils

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Abstract

Field experiments were conducted during *kharif* 2009 and 2010 with rice as the test crop under submerged conditions using different vermicomposts under integrated nutrient management (INM) at Regional Agricultural Research Station, Anakapalle, Andhra Pradesh, India. In the present study, *kharif* rice was grown with 12 treatments, consisting of different treatments. The data indicated that the values of available micro nutrient status, their uptake and humic substances were higher with INM practices, specially when vegetable market waste vermicompost was applied. With continuous chemical farming, there was a slight reduction in the soil micronutrient nutrient status, nutrient uptake and humic substances. Conjunctive application of organics along with inorganics exhibited higher grain and straw yields of rice with high micronutrient uptake and soil humic substances over application of inorganics only.

Key words: INM, micronutrients, humic substances, rice.

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Application of organic amendments to the soil system will significantly increase the humic fractions of soil and these fractions enhance the nutrient availability. The humic substances are the most active components of soil organic matter and have multiple effects that can greatly benefit plant growth (Zhang and Dousen, 2002). It is widely recognized that neither use of organic manures nor chemical fertilizers can achieve the sustainability of the yield under the modern intensive farming. The escalating costs of chemical fertilizers on one hand and undesirable effects on soil properties on the other have led to inclusion of organic manures in cultivation of crops. Application of organic manures in combination with inorganic fertilizers improves soil health and maximize sustainable productivity through increased soil humic substances which leads to higher availability of macro and micronutrients to crops. Hence, the present investigation involving vermicomposts obtained from various organic residues integrated with inorganic fertilizers was taken up to study the effect of Integrated nutrient management on micronutrient status, their uptake and humic substances under submerged rice soil.

Materials and Methods

A field experiment was conducted during *kharif* 2009 and 2010 consecutively for two years with rice as the test crop at Regional Agricultural Research Station, Anakapalle, Visakhapatnam district of Andhra Pradesh. The soil was clay loam in texture with neutral in soil reaction (pH 7.22) with non saline conductivity (0.21 dSm^{-1}). The organic carbon content was 0.51 % and the available zinc, copper, iron and manganese status in initial soils were 0.74, 1.10, 8.20 and 10.50 mg kg^{-1}, respectively. There were 12 treatments of integrated nutrient management imposed to rice crop. The treatments include T_1- 50 % RDF + 2.5 t ha^{-1} cane trash compost, T_2- 50 % RDF + 2.5 tha^{-1} weed compost, T_3- 50 % RDF + 2.5 t ha^{-1} vegetable market waste compost, T_4- 50 % RDF + 2.5 t ha^{-1} rice straw compost, T_5- 75 % RDF + 2.5 t ha^{-1} cane trash compost, T_6- 75 % RDF + 2.5 t ha^{-1} weed compost, T_7- 75 % RDF + 2.5 t ha^{-1} vegetable market waste compost, T_8- 75 % RDF + 2.5 t ha^{-1} rice straw compost, T_9- 100 % RDF, T_{10}- Absolute control, T_{11} -100 % Prathista organic manures and T_{12} -50 % Prathista organic manures + 50 % chemical fertilizers. Certified organic manures supplied by M/s Prathista Industries Ltd., Hyderabad, they produce and market the different organic products i.e., Suryamin for N supplement, Biophos and Biopotash for P&K supplements, Biozinc for Zinc supplement were tested along with different levels of chemical fertilizers. Different vermicomposts viz., cane trash, weed, vegetable market waste and rice straw vermicompost @ 2.5 t ha^{-1} were used along with different levels of chemical fertilizers i.e 50 % recommended dose of chemical fertilizers (40 kg N, 30 kg P_2O_5 and 20 kg K_2O ha^{-1}) and 75 % recommended dose of chemical fertilizers (60 kg N, 45 kg P_2O_5 and 30 kg K_2O ha^{-1}) to rice. Chemical composition of different vermicomposts and Prathista organic manures were presented in Table 1.

Available micronutrients (Zn, Fe, Cu and Mn) were extracted from soil by using DTPA reagent as per the procedure of Lindsay and Norvell (1978) and were determined using atomic absorption spectrophotometer. Grain and straw samples at harvesting stage were collected, oven dried, ground and total micronutrients viz., zinc, iron, copper and manganese in these samples were analysed in diacid extract by using an atomic absorption spectrophotometer (Varian AA 240 FS) and expressed as mg kg^{-1} (Piper, 1966). Concentration of nutrients was multiplied by yield for calculation of nutrients uptake. All the parameters were analysed in a randomized block design to list the variance of different treatments at 5 per cent level of significance.

Results and Discussion

Micro nutrient status in submerged rice soil at harvest

Irrespective of the treatments, the available micronutrient status (Zn, Fe, Cu and Mn) observed under integrated nutrient treatments were higher over chemical fertilizers alone and the contents were higher in second year than first year (Table 2). Considering the critical limits of Zn (0.65 m g kg^{-1}), Cu (0.2 mg kg^{-1}), Fe (4.5 mg kg^{-1}) and Mn (1 mg kg^{-1}), all the treatments were under sufficiency range except control. The treatment with T_7 : 75 % chemical fertilizers + vegetable market waste vermicompost @ 2.5 t ha^{-1} recorded significantly higher available micronutrient status except zinc. In both the years, the highest available zinc status was recorded with 100 % Prathista organic manures, however which was on par with T_7, where as lowest available zinc status was recorded in absolute control. The data revealed that the available iron and copper content in post harvest soils of rice ranged between 5.9 to 9.5 and 0.85 to 1.52 during 2009 and 5.4 to 10.2 and 0.74 to 1.64 mg kg^{-1} during 2010, respectively.

The results indicated that the available manganese status varied from 7.4 to 15.2 during 2009 and 7.0 to 16.5 mg kg^{-1} during 2010, respectively. More micronutrient build up was observed during second year over first year in all the integrated nutrient treatments. The results are well supported by the findings of Ramesh *et al.* (2006) and Banik and Sharma (2008). The higher availability of micronutrients in soil particularly with use of vermicompost may be ascribed to mineralization, reduction in fixation of nutrients by organic matter and complexing properties of humic substances released from vermicomposts with micronutrients (Prasad *et al.* 2010). The INM treatments with organic manures either increased or retained the critical fertility status of micronutrients. Organic manures on decomposition produce a variety of biochemical substances (organic acids, polyphenols, amino acids and poly saccharides) which stimulate the solubility, transport and availability of micronutrients. Effectiveness of vermicomposts may be ascribed to their ability after degradation to form water soluble complexes with iron and other ions. Perhaps, humic substances and organic acids formed after decomposition of crop residue by microflora may help in the translocation of iron which can be transported only with difficulty within the plant. The most significant influence of vermicomposts in increasing the solubility and availability of iron in the soil is through solubilization and mass flow in the immediate vicinity of plant (Prasad *et al.*, 2010).

Humic fractions (%) extracted from submerged rice soil

A close perusal of data presented in Table 3 revealed that humic and fulvic acid contents in soil was significantly influenced by the application of different vermicomposts. Humic acid content extracted from different treatments varied from 0.20 to 0.37 per cent during 2009 and 0.18 to 0.43 per cent during 2010. Highest humic acid content was recorded in the treatment which received 75 % recommended dose of nitrogen fertilizers + vegetable market waste @ 2.5 t ha^{-1}. In both the years, vegetable market waste vermicompost performed better than other sources of vermicomposts and it was on par with 75 % recommended dose of nitrogen fertilizers + weed compost @ 2.5 t ha^{-1}, 50 % chemical fertilizers + vegetable market waste vermicompost @ 2.5 t ha^{-1} and 100 % Prathista organic manures. All the INM treatments were superior to recommended dose of chemical fertilizers, however it was superior to absolute control (T_{10}) which recorded the lowest humic acid content.

Fulvic acid content also followed the similar trend like that of humic acid content. Application of organic manures enhanced the fulvic acid content in the soil. Highest fulvic acid content of 0.24 per cent was recorded in the treatment which received 75 % recommended dose of nitrogen fertilizers + vegetable market waste @ 2.5 t ha^{-1} during 2009 and it was slightly increased to 0.25 % during 2010. Lowest fulvic acid content was recorded in absolute control. All the INM treatments were superior to recommended dose of chemical fertilizers.

Application of different vermicomposts significantly enhanced the humic substances in soil. Among the different treatments, the higher humic acid content was recorded in the treatment which received 75 % chemical fertilizers + vegetable market waste vermicompost @ 2.5 t ha^{-1}. This could be due to the fact that the vegetable market waste contains high organic matter and its application to soil on decomposition increases the humic acid content in the soil. Similar results were obtained by Garcia *et al.* (2004). Gathala *et al.* (2007) reported that humic acid and fulvic acid contents got increased with application of organic amendments to the soil. Soil organic matter influences humic fractions by its ability to interact with metals, oxides, hydroxides and clay minerals to form metallo-organic compounds and act as ion exchanger and store house of nutrients. The increase in humic substances due to addition of different vermicomposts may be due to the fact that the organic manures added to the soil, on further decomposition released humic fractions. The increase in humic substances by integrated use of chemical fertilizers and organic sources was reported by Zhang and Dousen (2002).

Influence of INM on micronutrient uptake by rice

The data on zinc and copper uptake by rice grain and straw at harvest stage was presented in Table 4. The data obtained from different treatments indicated that the treatment effects on zinc and copper uptake was significant. Significantly highest zinc and copper uptake was recorded in the treatment which received 75 % chemical fertilizers + vegetable market waste vermicompost @ 2.5 t ha^{-1}. Significantly lowest zinc and copper uptake was recorded in absolute control. All the INM treatments were superior than the treatment with 100 % recommended dose of chemical fertilizers.

Ansari *et al.* (2008) observed that vermicompost application enhanced the activity of beneficial microbes and colonization of mycorrhizal fungi, which play an important role in mobilization of micronutrients, there by leading to better uptake by plants. The increased micronutrient uptake under integrated nutrient management practices was due to the production of organic acids during decomposition of organic matter, which are capable of releasing the nutrients associated with clay minerals and better availability from both organic and inorganic sources. Prasad *et al*. (2010) reported that the incorporation of vermicomposts increased the micronutrient uptake by rice. More over, the beneficial effect of vermicompost and fertilizer NPK on micronutrient uptake might be attributed to their increased humic substances, faster release of nutrients during mineralization, thereby resulting in higher uptake by rice owing to higher grain yield. In addition, vermicompost also contained different growth promoting substances which induced high dry matter yield leading to higher uptake of nutrients (Prakash and Bhadoria, 2003).

Grain yield of rice

Significantly higher grain yields were recorded when 25 % N was substituted through vegetable market waste vermicompost, which was on par with weed vermicompost (Fig.1). The higher grain yields of rice with integrated use of different vermicomposts and chemical fertilizers might be attributed to higher availability of macro and micro nutrients and facilitating uptake by plants resulting in better growth and dry matter production (Barik *et al*., 2008). Among different vermicomposts (cane trash, weeds, vegetable market waste and rice straw vermicomposts) used in the study, rice responded favourably to the addition of vegetable market waste vermicompost as a substitute for a part of chemical nitrogen fertilizer compared to application of other vermicomposts. This might be due to the rate of decomposition and C/N ratio of the vermicompost, which decide the availability of nutrients (Fateh Singh *et al*., 2008). Conjunctive application of organics along with inorganics sets a congenial soil environment with consistent supply of nutrients over the crop period by enhancing the crop growth which results in high yields.

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Table 1: Nutrient composition of different organic manures used in the study

Treatment	Total macronutrients (%)			Total micronutrients (mg kg^{-1})			
	N	P	K	Zn	Fe	Mn	Cu
Cane trash vermicompost	1.14	0.46	1.61	61	294	32	28
Weed vermicompost	1.88	1.01	1.31	81	365	67	36
Veg. market waste vermicompost	2.11	1.22	1.45	89	412	98	57
Paddy straw vermicompost	1.12	0.43	1.64	58	284	36	24
Suryamin	20	-	-	-	-	-	-
Biophos	-	20	-	-	-	-	-
Biopotash	-	-	14	-	-	-	-
Biozinc	-	-	-	12 %	-	-	-

Table 2: Effect of INM on micronutrient status (mg kg^{-1}) in post harvest soils of rice

Treatments	Zn		Fe		Cu		Mn	
	2009	2010	2009	2010	2009	2010	2009	2010
T_1: 50 % RDFN + CT VC @ 2.5 t ha^{-1}	0.81	1.02	7.6	8.1	1.06	1.24	11.6	12.7
T_2: 50 % RDFN + W VC @ 2.5 t ha^{-1}	0.98	1.31	8.4	8.9	1.22	1.45	12.4	13.2
T_3 : 50 % RDFN + VMW VC @ 2.5 t ha^{-1}	0.95	1.22	9.2	9.7	1.43	1.56	14.2	15.8
T_4: 50 % RDFN + PS VC @ 2.5 t ha^{-1}	0.79	0.98	7.8	8.3	0.98	1.20	10.7	12.1
T_5: 75 % RDFN + CT VC @ 2.5 t ha^{-1}	0.83	1.16	7.9	8.3	1.22	1.31	12.8	13.4
T_6: 75 % RDFN + W VC @ 2.5 t ha^{-1}	1.03	1.3	8.6	9.2	1.37	1.52	13.7	14.7
T_7 : 75 % RDFN + VMW VC @ 2.5 t ha^{-1}	1.04	1.26	9.5	10.2	1.52	1.64	15.2	16.5
T_8: 75 % RDFN + PS VC @ 2.5 t ha^{-1}	0.82	1.14	8.1	8.4	1.14	1.23	12.2	13.2
T_9: 100 % RDFN	0.7	0.74	7.5	7.6	1.01	1.02	10.2	10.5
T_{10} : Absolute control	0.64	0.58	5.9	5.4	0.85	0.74	7.4	7.0
T_{11}: 100 % Prathista organic manures	1.07	1.34	7.9	8.2	1.12	1.24	11.5	12.5
T_{12}: 50% RDF + 50% Prathista organic manures	1.01	1.25	7.7	8.0	1.07	1.15	10.8	11.5
S.Em$\pm$	0.031	0.033	0.25	0.29	0.046	0.051	0.045	0.049
CD (0.05)	**0.074**	**0.080**	**0.68**	**0.71**	**0.11**	**0.12**	**1.1**	**1.6**

Table 3: Effect of INM on soil humic substances (%) in post harvest soils of rice

Treatments	Humic acid (HA)		Fulvic acid (FA)	
	2009	2010	2009	2010
T_1: 50 % RDFN + CT VC @ 2.5 t ha^{-1}	0.31	0.36	0.16	0.17
T_2: 50 % RDFN + W VC @ 2.5 t ha^{-1}	0.35	0.39	0.19	0.21
T_3 : 50 % RDFN + VMW VC @ 2.5 t ha^{-1}	0.36	0.41	0.20	0.23
T_4: 50 % RDFN + PS VC @ 2.5 t ha^{-1}	0.32	0.36	0.17	0.19
T_5: 75 % RDFN + CT VC @ 2.5 t ha^{-1}	0.32	0.38	0.18	0.22
T_6: 75 % RDFN + W VC @ 2.5 t ha^{-1}	0.37	0.41	0.21	0.24
T_7 : 75 % RDFN + VMW VC @ 2.5 t ha^{-1}	0.37	0.43	0.24	0.25
T_8: 75 % RDFN + PS VC @ 2.5 t ha^{-1}	0.34	0.37	0.17	0.20
T_9: 100 % RDFN	0.28	0.28	0.14	0.16
T_{10} : Absolute control	0.20	0.18	0.12	0.11
T_{11}: 100 % Prathista organic manures	0.36	0.41	0.20	0.24
T_{12}: 50% RDF + 50% Prathista organic manures	0.34	0.38	0.21	0.23
S.Em$\pm$	0.012	0.015	-	-
CD (0.05)	**0.022**	**0.024**	**NS**	**NS**

Table 4: Effect of INM on zinc and copper uptake (g ha^{-1}) by rice grain and straw at harvest stage

Treatments	Zinc				Copper			
	Grain		Straw		Grain		Straw	
	2009	2010	2009	2010	2009	2010	2009	2010
T_1	52.80	67.60	45.60	68.20	105.60	130.00	108.30	130.20
T_2	78.20	102.60	59.00	75.60	128.80	156.60	129.80	144.90
T_3	86.40	112.00	66.00	91.00	148.80	190.40	144.00	169.00
T_4	47.30	60.00	52.20	61.00	98.90	120.00	116.00	134.20
T_5	60.00	78.40	63.00	81.60	120.00	145.60	126.00	156.40
T_6	93.60	120.00	78.00	91.00	150.80	186.00	143.00	175.00
T_7	99.00	124.00	80.40	100.80	171.60	210.00	166.40	187.20
T_8	57.60	71.50	67.10	88.40	115.20	137.50	122.00	149.60
T_9	46.00	52.80	48.00	59.40	92.00	100.80	102.00	112.20
T_{10}	19.60	12.00	25.90	12.80	44.76	33.60	44.40	32.00
T_{11}	62.40	84.00	70.40	89.70	176.00	210.80	167.50	193.20
T_{12}	59.40	80.60	72.60	84.00	167.40	204.60	165.00	182.00
S.Em$\pm$	2.21	2.47	-	3.04	4.78	5.05	4.33	5.08
CD (0.05)	**5.45**	**6.32**	**NS**	**6.54**	**10.55**	**11.68**	**10.75**	**11.87**

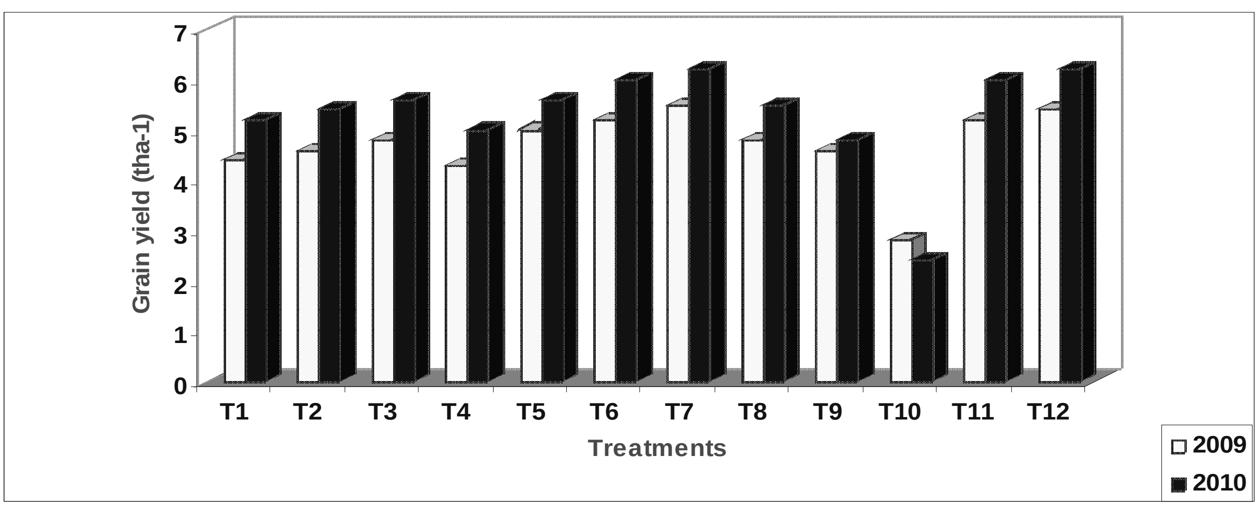

Figure 1: Effect INM on grain yield (t ha^{-1}) of rice

Short communication

Economics of Weed Management Practices in System of Rice Intensification (SRI)

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Abstract

Two field experiments were conducted during Thaladi and Kuruvai seasons in 2009 to 2010 at Annamalai University Experimental Farm in a factorial randomized block design with three replications. Eight treatments formed by combination of two age of seedlings (M_1 – 10 days old seedlings and M_2 – 15 days old seedlings) and four weed management practices (S_1 – conoweeding two times, S_2 – conoweeding four times, S_3 – pre-emergence application of butachlor @ 1.5 kg a.i. ha^{-1} + hand weeding on 35 DAT and S_4 – unweeded control). The results revealed that conoweeding four times and use of 15 days old seedlings gave the highest net return and BCR.

Key Words: System of rice intensification, weed management, age of seedlings, rice, yield, economics.

More than 90 per cent of world's rice is grown and consumed in Asia and it is the staple food for more than half of the global population. India that ranks first in terms of rice acerage (45.54 m ha) in the world stands second for its production (99.18 m t) owing to low productivity (2.18 t ha^{-1}). Rice production has to be increased in India to meet the increasing demand and particularly in Tamil Nadu state with the problems of drought, poor quality irrigation water, non-vailability and high cost of labour during peak season, shrinking resources and frequent and prolonged power cuts. Present days rice cultivation is less remunerative due to increased cost of cultivation. System of Rice intensification (SRI) is emerging as a new technology to increase the rice production besides it saves land, water, labour and other resources (Uphoff and Randriamiharisoa, 2002; Budhar *et al*., 2006; Hugar *et al*., 2009).

In order to study the economics of difference weed management practices in SRI, two field experiments were conducted in the Department of Agronomy Experimental Farm, Annamalai University, Tamil Nadu during Thaladi (August 2009 to January 2010) and Kuruvai (June 2010 to September 2010) seasons with Co 43 and ADT 43 rice varieties, respectively. The farm is situated at 11°24' North latitude, 79°44' East longitude and at an altitude of 5.79 m above MSL. The texture of the soil is clayey loam with a pH of 8.4 and was rated as low for available nitrogen (227 kg ha^{-1}), medium for available phosphorus (17 kg ha^{-1}) and high for available potassium (346 kg

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ha^{-1}). The experiments were laid out in a factorial randomized block design with three replications. The treatments formed by combination of two age of seedlings (M_1 – 10 days old seedlings and M_2 - 15 days old seedlings) and four weed management practices (S_1 – conoweeding two times, S_2 – conoweeding four times, S_3 – pre-emergence application of butachlor @ 1.5 kg a.i. ha^{-1} + hand weeding on 35 days after transplanting (DAT) and S_4 – unweeded control). Recommended package of practices were adopted for both the crops. Benefit of cost ratio was worked out by dividing the gross income by cost of cultivation.

The additional cost of cultivation due to various weed management practices ranged from Rs. 2018 to Rs. 3449 in Thaladi season (Table 1) and Rs. 2537 to Rs. 3594 in Kuruvai season (Table 2). Conoweeding four times was found to be cheaper than (Rs. 413 and 436) conventional method of butachlor application @ 1.5 kg a.i. ha^{-1} + hand weeding on 35 DAT. Conoweeding four times practiced in 15 days old seedlings gave the highest net return and BCR (Rs. 74652 and 3.48 in Thaladi season and Rs. 61750 and 2.98 in Kuruvai season). Similar BCR result was reported by Radhamani *et al*. (2012). In conoweeding four times, weeds are buried inside the soil and minimized the weed competition besides it improveing soil aeration, root development, nutrient absorption and more number of tillers which favoured the crop growth and resulted in higher grain yield, net income and BCR (Mishra and Sahoo, 1991; Norman Uphoff, 2002; Thiyagarajan *et al*., 2002). The next best treatment was conventional method of butachlor application @ 1.5 kg a.i. ha^{-1} + hand weeding. Conoweeding two times resulted in an additional net income of Rs. 35983 and BCR of 1.18 in Thaladi season and Rs. 23641 and 0.94 in Kuruvai season over unweeded control. Lowest net income and BCR was noticed in unweeded control. The trend of the treatments was same when practiced in 10 days old seedlings. From this study, it may be concluded that conoweeding four times was found to be efficient in controlling weeds, economical and gave the highest net income and BCR in SRI.

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Table 1: Economic analysis for Thaladi season

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross returns (Rs/ha^{-1})	Cost of cultivation (Rs/ha^{-1})	Net returns (Rs/ha^{-1})	BCR
M_1S_1	6003	7365	79401	29045	50356	2.73
M_1S_2	7493	8829	98745	30063	68682	3.28
M_1S_3	7197	8465	94830	30476	64354	3.11
M_1S_4	2859	3990	38298	27027	11271	1.41
M_2S_1	6503	7915	85951	29045	56906	2.95
M_2S_2	7975	9374	104714	30062	74652	3.48
M_2S_3	7673	9010	101086	30476	70610	3.31
M_2S_4	3600	4750	47950	27027	20923	1.77

Table 2: Economic analysis for Kuruvai season

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross returns (Rs/ha^{-1})	Cost of cultivation (Rs/ha^{-1})	Net returns (Rs/ha^{-1})	BCR
M_1S_1	5305	6531	75496	29954	29299	2.5
M_1S_2	6145	7525	87410	30575	44126	2.85
M_1S_3	5934	7282	84422	31011	40655	2.72
M_1S_4	2750	3852	39602	27417	8981	1.44
M_2S_1	5612	6897	76808	29954	37230	2.56
M_2S_2	6480	7881	91124	30575	61750	2.98
M_2S_3	6269	7638	89122	31011	58303	2.87
M_2S_4	3100	4280	44580	27417	13589	1.62

JUST RELEASED BOOK

International Dialogue on Perception and Prospects of Designer Rice

International Dialogue on Designer Rice was organized by the Society for Advancement of Rice Research (SARR) at ICRISAT, Hyderabad during 9-10 July, 2012 as a brain- storming session on the prospects of designing rice that would be capable of meeting the future food and nutritional needs. Rice researchers across the world participated in this dialogue capturing novel ideas and their feasibility, practicability in the context of existing scientific knowledge and tools in the futuristic scenario in all the relevant fields of rice.

The proceedings of the dialogue covered 8 themes viz., ***Genomic Resources: Status; Tailoring Rice by Design: Finding New Yield Thresholds; Engineering Starch Biosynthesis; True Breeding Apomixis; Defending Against Stresses: Biotic Stresses; Defending Against Stresses: Abiotic Stresses; Economizing Input Use: Nutrient And Water Use Efficiency; and Nutrient Rich Wholesome Rice.***

The proceedings encompassing 43 full length papers and 32 abstracts contributed by eminent scientists all over the world are available at the Directorate of Rice Research and the copies can be obtained from the Secretary, SARR by sending a Demand Draft for Rupees 600 for members of SARR and Rupees 1,000 for non-members.

Correct Citation: Muralidharan K and Siddiq EA, Editors. 2013. International Dialogue on Perception and Prospects of Designer Rice. Society for Advancement of Rice Research, Directorate of Rice Research, Hyderabad 500030, India. 386 p.

Journal of Rice Research

Instructions to authors for preparation and submission of papers:

Scope: **Journal of Rice Research** is a channel for publication of full length papers covering results of original research, invited critical reviews or interpretative articles related to all areas of rice science, rice based crop systems and rice crop management. The journal also publishes occasional short communications, book reviews and letters to the editor.

Articles reporting experimentation or research in any field involving rice or rice based cropping systems will be accepted as original articles while critical reviews are generally invited. Short articles concerned with experimental techniques or observation or observation of unique nature will be accepted as short communication. Letters to the editor concerning previous articles are welcome and are published subject to review and approval by the editorial board. The original authors will be invited to reply to the points raised in these letter for their response which are also published together.

General Requirement:

Submission to the journal must be reports of original research of at least two crop seasons and must not be previously published or simultaneously submitted to any other scientific or technical journal. At least one of the authors (incase of joint authorship) should be member of the Society for Advancement of Rice Research and not in arrears of subscription. Authors of invited articles are exempted from this.

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All manuscripts should be submitted in duplicate to the Chief Editor in hard copy along with a soft copy as word file. Manuscripts may also be sent online to the Journal office at sarr_drr@yahoo.com as an attachment. All the enclosed figures (as ppt files), graphs (as MS Excel worksheet with original data) and photographs (as jpg or ppt files with high resolution) may be submitted as separate files. Avoid using more than one font. The manuscript should be double spaced with margins of at least 2.5 cms. On the first page give the title, a byline with the names of authors, their affiliation and a foot note mentioning corresponding author and his/her e-mail ID –and a list of key words, and abbreviations used in the paper. An abstract must be presented normally on the second manuscript page. The usual order of sections to be included after title and abstract pages are : untitled introduction which includes literature review, materials and methods, results, discussion, conclusion (optional), acknowledgements and references followed by figures and tables. Results and discussions may be combined and conclusions can be given at the close of the discussion section.

Title and byline should give a clear idea what the articles is about. It should be as brief and informative (12-15 words). Use common names for crops preferably, botanical names if needed and avoid abbreviations. Below the title, list all names of the authors with an asterick placed after the name of the corresponding author and their affiliations.

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1. Mukherjee, J.N. 1953. The need for delineating the basic oil and climatic regions of importance to the plant industry. *Journal of Indian Society of Soil Science* 1: 1-6
2. Scott, J.M. 1984. Catabolism of folates. P.307-327. In R.L. Blackley and S.J. Benkovic (ed.) Folates and Pterims Vol.1. John Wiley & Sons, New York
3. Shin, Y.S., E.S. Kim,. Watson, J.E. and Stokstad, E.L. 1975. Studies on folic acid compounds in nature. IV. Folic acid compounds in soybeans and cow milk. Candian *Journal of Biochemistry*. 53:338-343

Figures: Photographs and drawings for graphs and charts should be prepared with good contract of dark and light. Figure caption should be brief specifying the crop or soil, major variables presented and lace and year. Give careful attention to the width of lines and size, and clarity of type and symbols.

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Careful observation of hints as indicated above will facilitate quick processing of the manuscripts and printing of the paper.

The manuscripts (one soft copy and two hard copies) typed in double space complete in all respects should be sent to :

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