STANDARDIZATION OF CROP ESTABLISHMENT TECHNIQUE FOR UPLAND RICE (*Oryza sativa* L.) IN COCONUT GARDEN

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"STANDARDIZATION OF CROP ESTABLISHMENT TECHNIQUE FOR UPLAND RICE (*Oryza sativa* L.) IN COCONUT GARDEN"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"STANDARDIZATION OF CROP ESTABLISHMENT TECHNIQUE FOR UPLAND RICE (*Oryza sativa* L.) IN COCONUT GARDEN"** is a record of research work done independently by Mr. Dhanu Unnikrishnan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

ANOVA	:	Analysis of variance
B: C	:	Benefit cost
CD (0.05)	:	Critical difference at 5 % level
CGR	:	Crop growth rate
CRS	:	Coconut Resarch Station
DAS	:	Days after sowing
DAT	:	Days after transplanting
DMP	:	Dry matter production
DSR	:	Direct seeded rice
dS m^{-1}	:	Deci Siemens per metre
EC	:	Electrical conductivity
et al.	:	Co-workers/ Co-authors
FAO	:	Food and Agriculture Organization
FYM	:	Farm yard manure
Fig.	:	Figure
G	:	Gram
GOI	:	Government of India
h^{-1}	:	Per hour
Ha	:	Hectare
ha^{-1}	:	Per hectare
$hill^{-1}$	:	Per hill
IRRI	:	International Rice Research Institute
i.e.	:	That is
K	:	Potassium
KAU	:	Kerala Agricultural University
kg^{-1}	:	Per kilogram
L	:	Litre

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LAD	:	Leaf area duration
LAI	:	Leaf area index
M	:	Molar
m^{-2}	:	Per square metre
Mg	:	Milligram
mL	:	Millilitre
M ha	:	Million hectare
M t	:	Million tonnes
MSL	:	Mean sea level
N	:	Nitrogen
NAR	:	Net assimilation rate
NS	:	Non-significant
P	:	Phosphorus
pH	:	Potenz hydrogen
$Panicle^{-1}$	:	Per panicle
q ha^{-1}	:	Quintal per hectare
RBD	:	Randomized block design
RGR	:	Relative growth rate
SEm	:	Standard error of mean
T	:	Tonnes
TPR	:	Transplanted rice
USDA	:	United States Department of Agriculture
viz.,	:	Namely

LIST OF SYMBOLS

%	:	Per cent
@	:	at the rate of
°C	:	Degree Celsius
₹	:	Rupee

Introduction

1. INTRODUCTION

Rice commends acceptance as a superior commodity to mankind, because rice is indeed life, a tradition, a culture and a way of livelihood to millions. It provides 60 to 70 per cent of total calorie requirement and hence considered as the most important staple food. Rice, the oldest domesticated grain crop (10,000 years) is the major source of energy for more than 2.5 billion people. It accounts for 21 per cent of global human per capita energy and also provides 15 per cent of per capita protein. It is the staple food for more than half of the world's population and is grown in more than 95 countries across the globe (IRRI 2002 ; Coats 2003).

Rice is cultivated in most of the countries, with global annual production of 481.70 million tons (USDA, 2018). Total production of rice in India during 2017-18 is estimated at a record of 112.91 million tonnes which has increased by 3.21 million tonnes than the production of 109.70 million tonnes during 2016-17. It is also higher by 6.61 million tonnes than the five year's average production of 106.29 million tonnes (GOI, 2018). The United Nations General Assembly celebrated 2004 as international rice year and Government of Kerala celebrated 2016 as rice year which signifies the importance of rice in food security and its role in alleviating poverty and malnutrition.

The worlds demand for rice is increasing and hence there is an urgent need to develop technologies for increasing the rice production. Upland rice production system is considered as one of the most sustainable alternative for enhancing rice production. Nearly 100 million people depends on upland rice as their staple food. Upland ecosystem is prominent in most of the Indian states, covering about 13.5 per cent of the area under rice and contributes four per cent of rice production.

Though rice is the staple food of Kerala, area under rice is decreasing day by day due to conversion of paddy land for housing, industrial purposes and other uses. The area under rice, the staple food crop of Kerala, had declined by 57 per cent between 1980 to 81 and 2000 to 01 and a further by 33 per cent between 2000 to 01 and 2009 to 10 (Viswanathan, 2014). In addition to this, conventional rice production systems (puddled transplanting) require large quantities of water. Rice is considered as an expensive consumer of water. Rice consumes about 50 per cent of total irrigation water used in Asia and accounts for about 24 to 30 per cent of the withdrawal of world total freshwater and 34 to 43 pe rcent of the world's irrigation water (Bouman *et al.*, 2009).

To meet the food requirements of people we have to enhance the production and productivity of rice with limited use of water resources as water is becoming scarce day by day. Enhancing the area under rice is one among the major solution to increase the production of rice in our state. Utilization of inter-row spaces in coconut garden having more than 25 years is one among the area that can be exploited to increase the area under rice. Studies conducted by CPCRI and Kerala Agricultural University revealed that upland rice come up very well in coconut garden having palms more than 25 years of age.

Dibbling/drilling/broadcasting of dry seeds is called direct seeded rice (DSR). It has several advantages, *viz*., more efficient water use, high tolerance to water deficit, less methane emission, reduced cost of cultivation, prevents the formation of hard pan in sub soil and minimize the labour input (Balasubramanian and Hill, 2002). It also conserves natural resources especially ground water and maintains physical properties of soil. The adoption of direct seeding of rice in flat beds along with adoption of recommended package of practices recommendations of rice crop resulted in enhanced rice grain yield (Pawar *et al.*, 2017).

Transplanting of seedlings is a method that is being used in rice. The yield losses due to weeds range from 36 per cent in case of transplanted rice and as high as 84 per cent in case of direct sown rice. But puddling operation in transplanted flooded rice consumes upto 30 per cent of total water requirement for rice (Chauhan and Opena, 2012). Moreover, the loss of water through puddling, surface evaporation and percolation is more in transplanted flooded rice system. A new method of transplanting in wet unpuddled soil (Thomba method) is practised in Konkan regions of Maharastra which saves considerable amount of irrigation water when compared to transplanted flooded rice system.

Lack of an appropriate stand establishment technique is the main drawback in the production of upland rice. Manual dibbling of dry seeds in lines is the crop establishment technique commonly adopted by the farmers. It needs huge labour. Because of high labour cost, acute labour shortage and low productivity the farmers are reluctant to raise upland rice. Hence it is very necessary to identify an appropriate crop establishment technique which maintains optimum plant population, crop growth and yield with more profit.

With this back ground the present study entitled "Standardization of crop establishment technique for upland rice in coconut garden" was carried out with the following objectives.

- To find out the most cost effective crop establishment technique for upland rice
- To assess its impact on growth and yield of rice.

Review of Literature

2. REVIEW OF LITERATURE

Lack of an appropriate stand establishment technique is an obstacle in improving the productivity of upland rice. Hence a study has been undertaken with an objective to find out the most cost effective crop establishment technique for upland rice and to assess its impact on growth and yield of rice. The current state of knowledge regarding the effect of establishment techniques, seed rate, seed priming, dry and pre-germinated seeds on growth attributes, yield, nutrient uptake, weed density and economics of rice is reviewed here.

2.1 EFFECT OF ESTABLISHMENT TECHNIQUES OF RICE

Direct sowing of rice refers to the process of establishing a rice crop from seeds sown in the field rather than transplanting seedlings from the nursery. At present, 23 per cent of rice is direct-seeded globally (Rao *et al.* 2007).

Direct seeded rice (DSR) crop can be cultivated by wet seeding, dry seeding or water seeding. In dry DSR, rice is established using several different methods, including, broadcasting of dry seeds on unpuddled soil after either zero tillage or conventional tillage, dibbling in a well prepared field and drilling of seeds in rows after conventional tillage. The seedbed condition is dry (unpuddled), and the seed environment is mostly aerobic; thus, this method is known as dry- DSR. This method is traditionally practised in rainfed upland, lowland and flood prone areas of Asia (Rao *et al.*, 2007). Dry DSR differs from transplanted rice (TPR) in terms of crop establishment as well as subsequent crop management practices. In upland paddy cultivation transplanting technique is not commonly practised, but a new method of transplanting in wet unpuddled soil (Thomba method) is practised in Konkan regions of Maharastra (Kumhar *et al.*, 2016)

2.1.1 Effect on Growth and Yield of Rice

Venkateswaralu (1977) reported that DSR gave significantly more productive tiller m^{-2} (256) than TPR (204) possibly due to greater plant population rather than more tillers per plant. Dingkuhn *et al.* (1990) recorded more dry matter accumulation in DSR as compared to TPR and the grain yield of DSR and TPR were similar when irrigation was scheduled daily and at 20 Kpa soil moisture tensions. Direct-seeded rice was found advantageous in securing more value of yield attributes, *viz*., number of panicles m^{-2}, number of filled grains per panicle and test weight (Budhar *et al*., 1990). For instance, Dingkuhn *et al*. (1991) observed a substantially higher paddy yield in DSR (3 t ha^{-1}) than TPR (2 t ha^{-1}) which was attributed to the increased panicle number, higher 1000 grain weight and lower sterility percentage.

Panda *et al.* (1994) found higher grain yield of rice cultivar *Govinda* coupled with more number of filled spikelets per panicle, grain weight per panicle and harvest index under transplanting in puddled field. Results of most of the field experiments and on-farm trials showed that upon proper management, comparable yield from DSR could be secured as that of TPR and this might be the reason why majority of the rice growing countries are striving hard to make a shift from transplanted to DSR (De Datta and Nantasomaran 1990; Ramaswamy *et al*. 1994; Peng *et al*. 1996).

Alexander and Martin (1995) also reported non-significant difference between TPR and DSR with respect to plant height. The plant height also did not differ significantly among the direct seeding treatments at any stage of crop except when the crop was only 30 days old. The plant height at 30 and 60 days after sowing/transplanting was significantly higher in transplanted rice as compared to direct-seeded rice. Plant height at 90 days after sowing (DAS)/transplanting (DAT) till harvest of transplanted and DSR did not differ significantly.

Singh *et al*. (1995) reported that the grain yield of rice-varieties was higher in direct sowing than transplanting (2.01 *vs* 1.99 t ha^{-1}). They also observed that direct seeding in lines produced significantly high panicles m^{-2}, panicle weight and panicle length when compared to transplanting. Miyagawa *et al*. (1998) reported that yield of DSR and TPR did not differ significantly in irrigated condition due to profuse vegetative growth and a large number of spikelets per panicle in North East Thailand.

Dry-seeded rice provides an opportunity for earlier crop establishment to make better use of early season rainfall (Tuong 2000). Goel and Verma (2000) reported that mean grain yield of direct and transplanted rice were of same magnitude (5.31 t ha^{-1}) at Karnal, Haryana. The yield attributing character such as panicles m^{-2} was significantly more in DSR whereas panicle length and 1000 grain weight were on par with TPR.

Kumar (2002) from Punjab agricultural university (PAU) reported that direct-seeded rice produced significantly more dry matter than transplanted rice (TPR) at all growth stages and maturity and this was attributed to the more plant population per unit area in DSR compared to TPR. The increase in dry matter was 56.5, 32.3, 18.2 and 15.9 per cent, respectively over TPR at 50, 75 and 100 DAS and maturity, respectively. With respect to yield, both direct seeding (wet, dry or water seeding) and transplanting have similar results (Kukal and Aggarwal 2002). Hobbs *et al.* (2002) reported similar yield levels of TPR and DSR. Panicle number per unit area was almost 150 per cent higher in DSR than TPR, but grain weight per panicle was higher in the transplanted crop.

Ganesh (2002) reported that TPR gave significantly higher grain yield (6.3 t ha^{-1}) than DSR (4.8 t ha^{-1}) under puddled ponded condition. However, under limited irrigation conditions, the grain yield was on par in transplanted and direct sown crop. The DSR in moistened soil produced taller plants, more dry matter, lower chlorophyll content and specific leaf weight and more panicles and spikelets than TPR (Sarkar *et al.* 2003). The number of effective tillers and biomass yield were significantly higher in all the direct seeded methods than transplanting (Tripathi *et al.*, 2004).

Singh *et al.* (2001), Prasad *et al.* (2001), Parihar (2004) and Chaudhary *et al.* (2004) reported that TPR gave significantly higher grain yield, straw yield, yield attributes and net returns than DSR both under puddled and unpuddled conditions. Yield in DSR is often lower than transplanted principally owing to poor crop stand and high weed infestation (Singh *et al.*, 2005). Zhu (2008) documented that sowing of rice in dry DSR system increased the grain yield by 22 per cent and reduced the water input by 6000 $m^3 ha^{-1}$ compared with transplanted-flooded rice.

Sudhir-Yadav *et al.* (2011) observed that crop performance in terms of tiller density, leaf area index (LAI) and growth rate were better in DSR than TPR with daily irrigation scheduling at 20 KPa. Stevens *et al.* (2012), in a study conducted in Mossouri, USA, reported that dry DSR reached 10.3 t ha^{-1} grain yield with 750 mm water input which was far below the water input in transplanted-flooded rice.

2.1.2 Effect on Nutrient Uptake

Since different methods of crop establishment had uniform management practices, a high yield in the dry-seeded crop will mean higher nutrient use efficiency (NUE) than other establishment methods. This can be explained on the basis of root characteristics such as root number and average and maximum root length.

In direct seeding, availability of several nutrients including N, P, S and micronutrients such as Zn and Fe, is likely to be a constraint (Ponnamperuma, 1972). In addition, loss of N due to denitrification, volatilization and leaching is likely to be higher in dry DSR than in TPR (Davidson 1991; Singh and Singh 1988).

Nitrate accumulated in the soil during the dry fallow period will not be denitrified because of the absence of early flooding as in puddled soil. However, the availability of micronutrients such as Zn and Fe may be reduced under aerobic conditions, especially in the high pH saline soils that are widespread in the Indo-Gangetic plains (Balasubramanian and Hill, 2002).

Gupta *et al.* (2003) reported 10 per cent higher yield in DSR than flooded transplanted rice. Micronutrient deficiencies are of concern in DSR; imbalances of such nutrients (e.g. Zn, Fe, Mn, S and N) result from improper and imbalanced N fertilizer application (Gao *et al.*, 2006). Zhang *et al.* (2006) reported that total N uptake and nutrient use efficiency (NUE) were positively correlated with grain yield of rice. They suggested that based on high total N uptake at maturity, it was important to improve NUE to both increase yields and profit, and thus suitable for improving the cultivation and breeding in dry DSR.

Gobi *et al*. (2008) concluded that line planting with 50 hills m^{-2} registered significantly higher N uptake at tillering stage, whereas broadcasting with 40 hills m^{-2} recorded higher N uptake during flowering and harvest stages respectively. Seedling broadcasting with 40 hills m^{-2} registered significantly higher P and K uptake. Nitrogen use efficiency in dry DSR was different from that in transplanted-flooded rice. With optimal water management, dry DSR can achieve nitrogen use efficiency of over 80 per cent (Wilson *et al.* 2000), much higher than that in transplanted-flooded rice (30 to 40 per cent) (Zheng *et al.* 2007).

General recommendations for NPK fertilizers are similar to those in puddled TPR except that a slightly higher dose of N (22.5-30 kg ha^{-1}) is suggested in DSR to compensate for the higher losses and lower availability of N from soil mineralization at the early stage as well as the longer duration of the crop in the main field in dry DSR (Kumar and Ladha 2011).

2.1.3 Effect on Weed Density

Direct sowing of rice is quicker, easier and economical one, but the infestation of weeds in such crop is the main problem. Weed pressure is often two to three times more in DSR as compared to transplanted one.

Weeds are more problematic in direct seeded rice than in TPR. Pillai and Rao (1974) reported the extent of yield reduction due to infestation of weeds was 15 to 20 per cent under transplanted system and 30 to 35 per cent under direct seeded system. It is hypothesized that narrow row spacing may decrease the interval of critical weed competition periods. Akobundu and Ahissou (1985) reported that row spacing (15 to 45 cm) in DSR had little impact on the grain yield of the crop in the absence of weeds but in competition with weeds, the widest spacing resulted in significantly lower grain yield.

It has been observed that under moisture stress conditions, weeds grow faster than the rice plants (Singh and Bhattacharyya, 1989) and yield losses due to weeds range from 36 per cent in case of transplanted rice and as high as 84 per cent in case of DSR. Studies has shown that in the absence of effective weed control options, yield losses are greater in DSR than in TPR (Baltazar and De Datta 1992; Rao *et al*., 2007).

Dry seeding of rice provides an option to increase productivity in rainfed lowland rice ecosystems. Wider adoption of dry-seeded rice, however, is hindered by many problems, the major ones being poor stand establishment and high weed infestation (My *et al*., 1995, Saleh and Bhuiyan 1995). In upland DSR, it becomes difficult to keep the surface submerged throughout and hence it becomes conducive for germination and growth of the weeds, even in repeated flushes.

Prasad *et al*. (2001) observed that method of rice establishment had marked effect on weed count and weed dry weight. Subramanian and Martin (2005) reported that weed flora of the experimental field at Coimbatore was composite in nature consisting of grasses, sedges and broad leaved weeds. The major graminaceous weeds were *Echinochloa colona, Echinochloa cruss-galli* and *Leptochloa chinensis* and weed species belonging to the family Cyperacea were *Cyperus difformis, Cyperus rotundus* and *Cyperus iria*. The broad leaved weeds included *Eclipta alba*, *Ludwigia parviflora* and *Marsilea quadrifolia*

Puddled sowing of sprouted seeds recorded the lowest values of weed count and weed dry weight than dry drilling. The problem of grassy weeds was more in DSR as compared to other methods (Singh and Kumar, 2005). Results obtained by Singh *et al*. (2006) indicated that continuous infestation of weed in rice resulted in 56.89 per cent reduction in grain yield. Grain yield increased significantly with increase in initial weed free duration upto 45 days in rice. However, further increasing weed-free period did not improve grain yield markedly.High weed infestation is a major constraint for broader adoption of DSR (Rao *et al*., 2007).

In a recent study, seedlings of *Echinochloa colona* and *Echinochloa crus-galli* emerging during the first month of the crop growing season had greater biomass and seeds in aerobic rice planted at 30cm rows than at 20cm rows (Chauhan and Johnson, 2010). Chauhan and Johnson (2010, 2011) reported that weed count was observed to be more due to more space available in wider row spacing and also that rice crop sown in wider spacing were vulnerable to weed competition for the longest period (49 days) as compared with narrower spacing (39 days) and had greater weed biomass.

2.1.4 Effect on Economics of Rice Production

The main difference between upland and lowland rice is the difference in method of planting/sowing. Direct seeding is common in upland rice whereas transplanting is widely practised in lowland rice. Direct seeding and transplanting rice also differs in the amount of labour used for crop establishment. The direct seeded crop required only 34 per cent of the total labour requirement of the transplanted crop.

In a study, Erguiza *et al*. (1990) found that total paid out costs were 16 per cent higher for transplanted rice, largely because of the high cost of hired labour for crop establishment. Analytical studies on labour use by Wong and Morooka (1996) indicated that on an average, farmers used only 80 person h ha^{-1} per season in direct seeding compared with 237 person h ha^{-1} per season for transplanting. This resulted in labour saving of 157 person h ha^{-1} per season.

Budhar and Tamilselvan, (2001) recorded that the net income and benefit: cost ratio (B:C) were the highest in wet seeding by manual broadcasting closely followed by wet seeding by a drum seeder. After studying the economic effect of DSR cultivation, Lee *et al*. (2002) reported that the labour requirement from tillage to seeding in dry seeding was 41 h ha^{-1}, which was 73 and 23 per cent lower than that of machine transplanting and wet seeding, respectively. The total labour requirement for dry seeding was approximately 234 h ha^{-1}, which was 30 and 50 per cent lower than that of transplanting and wet seeding respectively. Thus, the total cost of rice production by direct seeding was about 21 per cent lower than machine transplanting.

Pandey *et al*. (2002) reported 50 per cent lower labour use in DSR than TPR. The total production cost for transplanting was higher than DSR. The difference was mainly due to the higher labour requirement for transplanting.

The economic analysis based on experimental data and farmers' interview revealed that the highest net return of 33 per cent was achieved from drill DSR followed by zero-tillage DSR (22 per cent) and wet seeded rice (21 per cent) over conventional TPR. The saving of 44 per cent in drill direct seeded, 45 per cent in zero-tillage direct seeded and 32 per cent in wet direct seeded were recorded in the total variable costs as compared to conventional TPR.

Wet seeding could result in a higher net income and benefit: cost ratio than traditional transplanting method. Establishment cost, irrigation cost and weed management cost appeared to be three main variable costs influencing the economics of different methods of rice cultivation (Tripathi *et al*., 2004).

In addition to higher economic returns, DSR are faster and easier to plant and less labour intensive (Jehangir *et al*., 2005). While considering the net monetary returns and B : C ratio due to different sowing method of rice, Jha *et al*. (2006) reported that direct seeding of sprouted seed with drum seeder produced higher net returns of Rs.30473 ha^{-1} with B : C ratio of 2.37 as compared to transplanting with net return of Rs.28000 ha^{-1} and B: C ratio 2.27.

Research on farmers' fields showed that DSR was profitable to farmers, giving net returns of Rs.13350 ha^{-1} for direct seeding and Rs. 11,592 ha^{-1} for wet seeding compared to Rs.10343 ha^{-1} for puddled TPR (Yadav *et al*., 2006). Total saving was around Rs.3500 ha^{-1} due to saving in labour and seed in broadcast method as compared to transplanting method (Jayawardena and Abeysekera, 2006).

Singh *et al*. (2006) reported higher profitability under reduced till DSR and zero-tillage DSR by Rs.2745 and Rs.3139 ha^{-1}, respectively compared to transplanted rice in western Uttar Pradesh and Haryana. Similarly, Gupta *et al*. (2006) reported that the net returns were higher in unpuddled transplanted compared to puddled transplanted conditions by Rs.940 and 4151 ha^{-1} in western Uttar Pradesh and Haryana, respectively.

Labour saving of DSR reduces 11.2 per cent of total production cost as well as DSR methods have several advantages over transplanting as reported by Naresh *et al.* (2010). Thus, it is necessary to change the cultivation system from transplanting to DSR (Sanjitha Rani and Jayakiran, 2010). Kumar (2011) also recorded similar findings and found higher B: C ratio in direct seeded rice DSR as compared to TPR.

2.2 EFFECT OF SEED RATE ON GROWTH AND YIELD OF RICE

Seed rate has a great impact on plant density and the competitiveness of the crop stand, tillering time to maturity and yield. Low plant density and improper sowing method are the most important factors of agronomic constraints for obtaining higher yields and have a positive influence on the yield of rice.

Direct seeding technique offers a useful option to reduce the limitations of TPR. Higher seed rate can result in large yield loss due to excessive vegetative growth before anthesis followed by a reduced rate of dry matter production (DMP) after anthesis (Wells and Faw 1978).

The increase in plant density increases total plant weight per unit area and decreases the total weight per plant (Yoyock *et al.,* 1979). Lower seed rate can be used for high-tillering varieties and a little higher seed rate for medium-tillering types (Soo *et al.,* 1989). High seed rates can result in lower foliage nitrogen (N) concentration at heading stage (Dingkuhn *et al.,* 1990).

Optimum plant density is the primary factor for obtaining higher yield in rice (Sivaesarajah *et al.,* 1995). The increase in plant density increases the yield up to a limit and thereafter a leveling off or decline in yield (Sivaesarajah *et al.,* 1995). Dwivedi *et al.* (1996) observed that the TPR (15 cm x 15 cm with 2 seedlings per hill) gave significantly more growth, higher grain yield and net returns. Random transplanting of single seedling per hill also resulted in higher yield and net returns with more growth than direct sowing of seeds.

Singh *et al.* (1997) reported through field experiment conducted with rice cultivar *Aswani* which was sown at the rate of 60, 70 and 80 kg ha^{-1} and N applied at 60 kg ha^{-1}, the highest grain yield was with the application of 60 kg N ha^{-1} under the seeding rate of 80 kg ha^{-1}.

The plants at low seed rate have sufficient space and this enables to utilize more nutrients, water and solar radiation for better photosynthesis. Hence, the individual plants performed better. This is in agreement with the studies reported by Baloch *et al.* (2002). The studies of Kathiresan and Manoharan (2002) revealed that the seed rate of 150 kg ha^{-1} registered the highest grain yield but on par with 125 kg ha^{-1} and both the seed rates were significantly higher than 100 kg ha^{-1}. The higher seed rate recorded 4.4 and 13.1 per cent more grain yield than 125 and 100 kg ha^{-1} respectively. Also the studies showed that the seed rate of 100 kg ha^{-1} under broadcasting method was better in achieving higher yield coupled with more productive tillers m^{-2} and higher test weight.

Baloch *et al.* (2007) and Kabir *et al.* (2008) revealed that higher seed rate resulted in higher spikelet sterility and fewer grains per panicle. Moreover, dense plant populations at high seed rate can create favourable conditions for diseases and insects thus making the plants more prone to lodging (Dofing and Knight, 1994; Islam *et al.*, 2008). Wu *et al.* (2008) in China found a seed rate of 20 to 25 kg ha^{-1} as optimum for DSR.

The reason for the reduction in yield is due to the reduction in resources per plant. So the reduction in yield will not be compensated by increasing plant number The number of plants per unit area has an impact on plant architecture, modifies growth and development pattern and effect on photosynthesis and production (Abuzar *et al.*, 2011).

2.3 EFFECT OF DRY AND PRE-GERMINATED SEEDS ON GROWTH AND YIELD OF RICE

In dry seeding system, rice is grown as any other upland crop by sowing the dry seed on well prepared dry or moist but not puddled soil. Seeds may be broadcasted or sown behind the plough or sown in lines by a seed drill in a well pulverized or zero-tilled field. Piggin *et al.* (2002) observed that the yield of dry seeded rice varied from 2.5 to 4.3 t ha^{-1} for unpuddled condition whereas yield of wet seeded were much lower (1.2 to 3.3 t ha^{-1}) due to strong winds and rain which caused lodging and shattering.

Fukai (2002) reported that drill direct seeding (5.5 t ha^{-1}) was significantly superior to TPR (5.1t ha^{-1}) and marginally superior to broadcasted wet seeded rice (5.2 t ha^{-1}) in grain yield. The higher number of panicles per unit area in drill direct seeding as compared to other methods was reason for obtaining higher yield. Tripathi *et al.* (2004) also reported that drill direct seeding of rice produced significantly higher grain yield over broadcast dry seeded, however, it was on par with broadcasted wet seeded and conventional transplanted rice.

According to Pandey and Velasco (2005), dry seeding has been the principal method of rice establishment since the 1950s in developing countries In dry DSR, seeds can be sown before the start of the wet season permitting the use of early rains for crop establishment.

Singh *et al.* (2006) reported that direct seeding of sprouted seeds under puddled condition produced higher grain and straw yield of rice which was on par with dry direct seeding but significantly higher than unpuddled DSR.

2.4 EFFECT OF SEED PRIMING ON GROWTH AND YIELD OF RICE

Soaking seeds of three upland rice varieties in water for 24 h, followed by air drying, improved stand establishment by 23 to 43 per cent, compared with non-primed seeds and grain yield by 11 to 24 per cent over three consecutive years (Singh and Chatterjee, 1981). Seed priming is a promising strategy that may permit direct field sowing providing enhancement of the physiological performance of seeds and helping to resolve the challenge of poor stand establishment (Bradford *et al.*, 1990; Farooq *et al.*, 2011). Seed priming is commonly used to reduce the time between seed sowing and seedling emergence (Parera and Canliffe, 1994). Seed priming tools have the potential to improve emergence and stand establishment under a wide range of field conditions (Phill, 1995).

Farmers' opinions on seed priming tend to agree with those reported by Harris *et al.* (1999) that primed crops emerge faster and more completely, produce more vigorous seedlings, flower and mature earlier, and yield better than non-primed crops. Priming rice seeds for 12 and 24 hours improved crop establishment and subsequent growth (larger leaf area, taller plants, higher root and shoot dry weights measured four weeks after sowing) and also had significantly more tillers, panicles and grains per panicle (Harris *et al.,* 1999). On-farm priming in DSR has increased the rate of germination and emergence by one to three days, resulting in more uniform and vigorous seedling growth (Harris *et al*., 2002).

The primed seeds germinated faster than unprimed seeds when placed in an appropriate germination environment. It is a physiological seed enhancement process for improving the germination characteristics of seeds. As compared to un-primed seeds, higher grain yield in primed seeds might have been due to rapid and regulated production of emergent metabolites leading to healthier, vigorous seedlings and improved leaf area index (LAI) (Basra *et al.,* 2005).

As DSR is sown during rainy season, heavy rains after sowing may result in poor germination. It is hypothesized that seed priming may counteract the aberrant weather conditions during germination, promote early crop vigour and result in better establishment of DSR. It may also enhance the performance of DSR by improving drought resistance by maintaining tissue water potential and enhancing the capacity to express antioxidant systems, especially during the vegetative phase, as the crop experiences high air temperatures (>35°C) during that time. Hydro priming involves partial hydration to a point where germination-related metabolic processes begin but radical emergence does not occur (Farooq *et al.,* 2006). Farooq *et al.* (2006) also observed that for rice sown in aerated soils, seed priming enhances seedling emergence, grain quality and yield.

Seed priming treatments significantly affected the leaf area duration (LAD). All the seed priming treatments resulted in improved LAD except traditional soaking, which behaved similar to that of untreated control. Seed priming treatments resulted in improved crop growth rate (CGR) except traditional soaking that behaved similar to that of untreated control (Farooq *et al.,* 2006)

Primed seeds usually exhibit increased germination rate, uniform and faster seedlings growth, greater germination uniformity, greater growth, dry matter accumulation, yield, harvest index and sometimes greater total germination percentage (Farooq *et al.,* 2006; Kaya *et al.,* 2006).

Priming technique allows some metabolic processes to occur without actual germination (Basra et al., 2005). Seed priming also reduced the need for high seeding rates, but was detrimental for seedling establishment when soil was at or near saturation (Du and Tuong 2002; Farooq *et al.*, 2011).

Seed priming also enhanced the starch hydrolysis, making more sugars available for embryo growth, vigorous seedling production and improved growth, grain yield and quality attributes at maturity (Farooq *et al.,* 2006).

Osmo-hardening with KCl led to higher grain yield (3.23 t ha^{-1}), straw yield (9.03 t ha^{-1}) and harvest index (26.34%) as compared to 2.71 and 8.12 t ha^{-1} kernel and straw yield, respectively and 24.02 per cent harvest index under untreated control in direct-seeded medium grain rice. Likewise, seed priming improved grain quality in fine grain and medium grain rice under DSR (Farooq *et al.*, 2006).

Higher yield was attributed to more tillers, 1000 grain weight and kernel yield while quality was attributed to improved grain protein and grain water absorption ratio (Farooq *et al.,* 2006). Primed seeds help in improving seedling density per unit area and LAI under optimal and adverse soil conditions. Seed priming could be adopted to improve the performance of dry-DSR (Mahajan, 2015).

Materials and Methods

3. MATERIALS AND METHODS

The field experiment for the investigation entitled "Standardization of crop establishment technique for upland rice in coconut garden" was conducted during *Kharif* 2018 (May to September 2018) at Coconut Research station (CRS), Balaramapuram, Thiruvananthapuram. The main objectives of the study were to find out the most cost effective crop establishment technique for upland rice and to assess its impact on the growth and yield of rice.

3.1 GENERAL DETAILS

3.1.1 Location

The experiment was conducted at CRS, Balaramapuram, Thiruvananthapuram, Kerala located at 8° 22' 52" North latitude and 77° 1' 47" East longitude and at an altitude of 9 m above mean sea level.

3.1.2 Climate

A warm humid climate prevailed over the experimental site. The data on daily weather parameters like mean temperature, relative humidity (RH), rainfall and evaporation were collected from the Class B Agromet observatory attached to CRS, Balaramapuram. The rainfall received during the crop season was 952.3 mm. The mean maximum and minimum temperature recorded during the crop season were 31.12 and 19.27 °C, respectively. The mean weekly weather data prevailed during the cropping period is presented Fig. 1.

3.1.3 Cropping Season

The field experiment was conducted during 2018 *Kharif* season (May to September 2018).

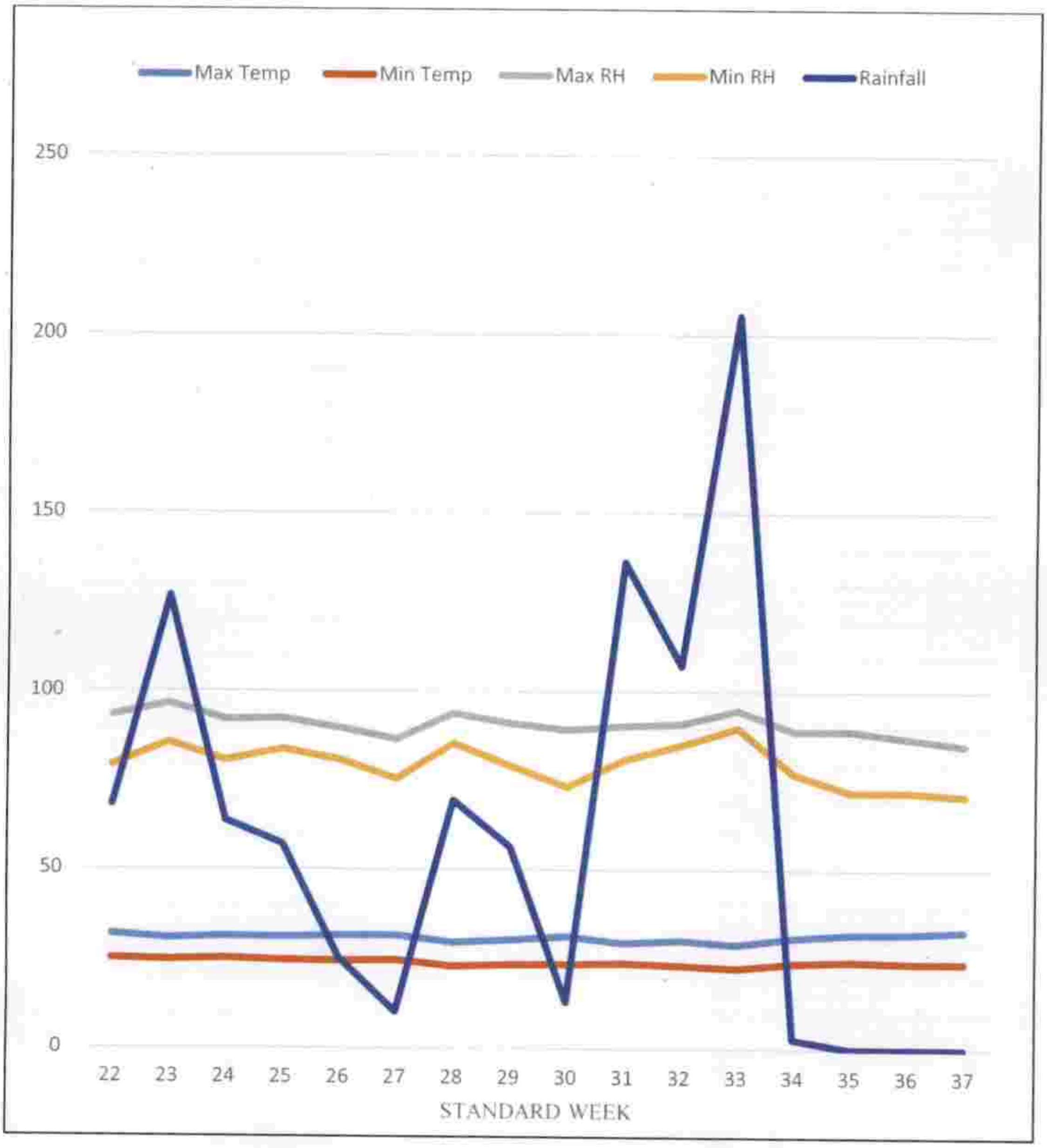

Fig.1. Weather parameters during May to September, 2018

Table 1. Physico - chemical properties of the soil before the experiment

A. Mechanical composition

Sl. No.	Fractions	Content in soil, per cent	Method
1	Sand	66.39	Bouyoucous hydrometer method (Bouyoucous,1962)
2	Silt	18.26	
3	Clay	15.28	

B. Chemical properties

Sl. No.	Parameters	Content	Method adopted
1	Soil reaction	4.6 (Acidic)	pH meter (1:2.5 soil water ratio) (Jackson, 1973)
2	EC, dSm^{-1}	0.10 (Normal)	Conductivity meter (1:2.5 soil water ratio) (Jackson, 1973)
3	Organic carbon, per cent	0.79 (Medium)	Walkley and Black rapid titration method (Walkley and Black, 1934)
4	Available N, kg ha^{-1}	301.50 (Medium)	Alkaline permanganate method (Subbiah and Asijia, 1956)
5	Available P, kg ha^{-1}	21.10 (Medium)	Bray colorimetric method (Jackson, 1973)
6	Available K, kg ha^{-1}	93.07 (Low)	Ammonium acetate method (Jackson, 1973)

3.1.4 Soil

Before conducting the experiment, a composite soil sample was taken for initial analysis. The experimental site was red sandy loam, acidic in reaction, medium in organic carbon and available N and P and low in available K status. The important physico - chemical properties of the soil are presented in Table 1.

3.1.5 Cropping History of the Field

The crop was raised as an intercrop in a 55 year old coconut garden where coconut is planted at a spacing of 7.6 m x 7.6 m. The inter row space of coconut had banana crop during the previous season.

3.2. MATERIALS

3.2.1 Crop Variety

Harsha (PTB-55) a short duration (100-110 days) variety having red, long bold grains released from Regional Agricultural Research Station, Pattambi, Palakkad, Kerala was used for the experiment. The variety is photoinsensitive and moderately resistant to brown plant hopper, sheath blight and sheath rot.

3.2.2 Source of Seed

The seed was procured from Regional Agricultural Research Station, Pattambi, Palakkad, Kerala.

3.2.3 Manures and Fertilizers

Farm yard manure (FYM) (0.45 per cent N, 0.17 per cent P_2O_5 and 0.5 per cent K_2O content) was used as the source of organic manure. Source of NPK for the experiment were urea (46 per cent N), rajphos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O).

3.3 METHODS

3.3.1 Design and Lay Out

Treatments	: 10
Replication	: 3
Season	: *Kharif* 2018
Spacing	: 20 cm x 10 cm
Gross plot Size	: 3 m x 3 m
Net plot size	: 2.6 m x 2.6 m (line sowing)
	: 2.7 m x 2.7 m (broadcasting)
	: 2.7 m x 2.8 m (thomba method at 15 cm x10 cm)
	: 2.6 m x 2.8 m (thomba method at 20 cm x10 cm)

Total number of plots: 30

3.3.2 Treatment Details

T_1- Line sowing dry seeds 60 kg ha^{-1}

T_2- Line sowing hydroprimed seeds 60 kg ha^{-1}

T_3- Broadcasting dry seeds 80 kg ha^{-1}

T_4- Broadcasting hydroprimed seeds 80 kg ha^{-1}

T_5- Broadcasting dry seeds 100 kg ha^{-1}

T_6- Broadcasting hydroprimed seeds 100 kg ha^{-1}

T_7- Broadcasting pre-germinated seeds 80 kg ha^{-1}

T_8-Broadcasting pre-germinated seeds 100 kg ha^{-1}

T_9-Thomba method of planting 15 cm x10 cm

T_{10}-Thomba method of planting 20 cm x10 cm

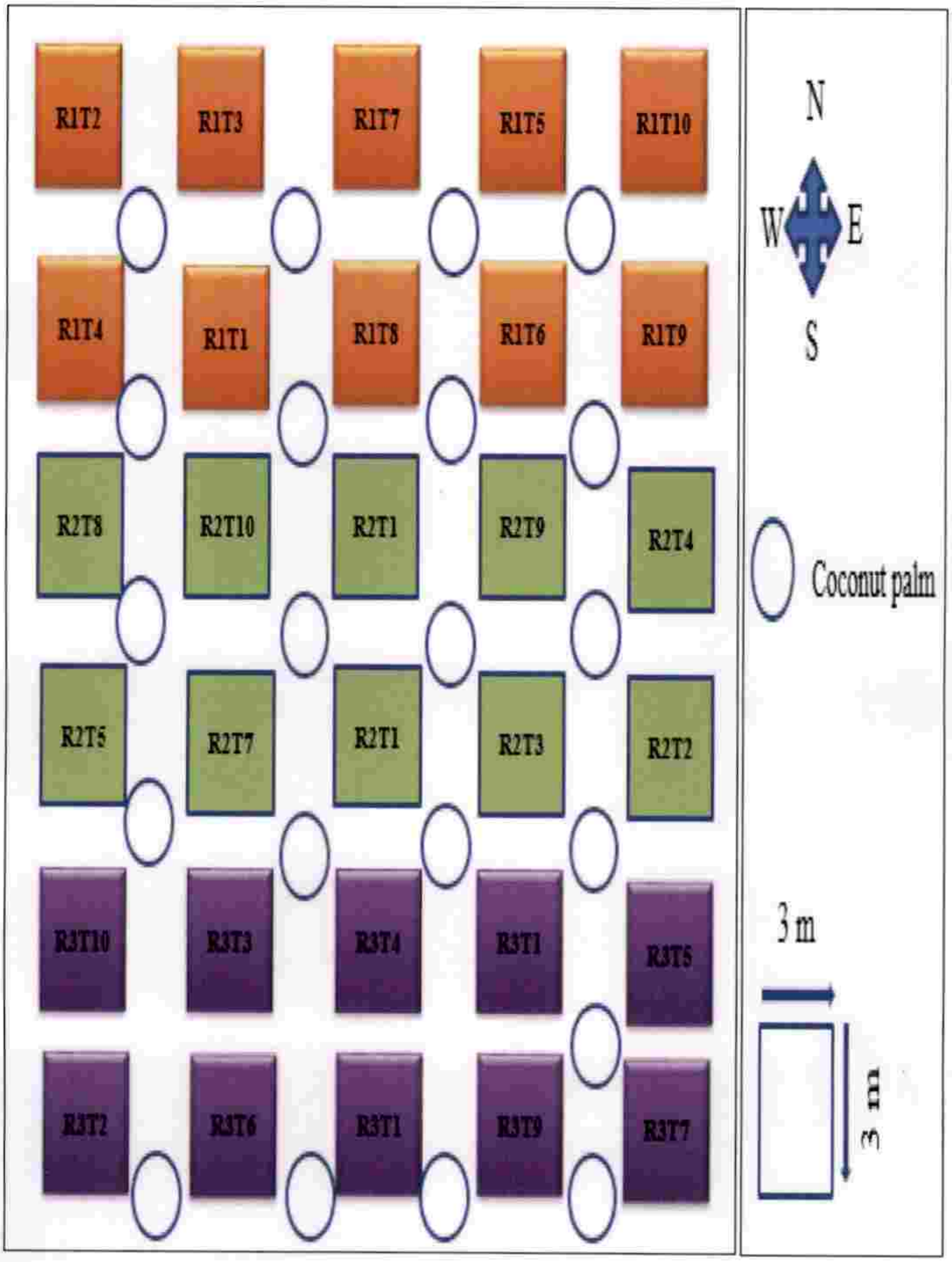

Fig 2. Lay out of experimental field

Plate1. General view of the experimental field

3.3.3 Field Preparation and Lay Out

The experimental area (excluding coconut basins) was thoroughly ploughed twice with power tiller and was uniformily levelled. After levelling, the individual plots were laid out as per the technical programme.

3.3.4 Application of Lime

Recommended dose of lime (600 kg ha^{-1}) was uniformly applied to all plots in two splits, 350 kg ha^{-1} at the time of last ploughing and 250 kg ha^{-1} at one month after sowing.

3.3.5 Seeds and Sowing

The dry paddy seeds were dibbled at a spacing of 20 cm x 10 cm and the seed rate adopted was 60 kg ha^{-1} in the treatment T_1. In broadcasting dry seeds, the seeds were broadcasted at a seed rate of 80 kg ha^{-1} in the treatment T_3. The hydroprimed seeds were dibbled at a spacing of 20 cm x 10 cm in the treatment T_2. The seed rate adopted was 60 kg ha^{-1}. They were also broadcasted at a seed rate of 80 kg ha^{-1} and 100 kg ha^{-1}, respectively in the treatments T_4 and T_6. For hydropriming, seeds were soaked in water for 16 hours and dried back to original moisture content by shade drying. Pre-germinated seeds were broadcasted at a seed rate of 80 kg ha^{-1} and 100 kg ha^{-1}, respectively in the treatments T_7 and T_8. Thomba method of transplanting was practiced at two different spacings 15 cm × 10 cm in the treatment T_9 and 20 cm × 10 cm in the treatment T_{10}. Thomba method of planting was the transplanting of seedlings in unpuddled wet soil. For thomba method, a mat nursey was prepared and seeds were sown by broadcasting. Fifteen days old seedlings from the mat nursery were separated and planted in the main field.

3.3.6 Application of Manures and Fertilizers

FYM (5 t ha^{-1}) was applied uniformly to all the plots along with the second land preparation and NPK @ 90:30:45 kg ha^{-1} was applied uniformly to all plants (Suman, 2018). Entire dose of P (30 kg P_2O_5 ha^{-1}) was provided uniformly to all plots just before sowing the seeds, incorporated well into the soil and levelled uniformly.

Nitrogen and potassium were applied in three equal splits at 12, 35 and 55 days after sowing (DAS).

3.3.7 Water Management

The crop was raised as rainfed crop and life saving irrigation was given as and when required.

3.3.8 Weed Management

Weed management was done by an early post emergent application of pyrazosulfuron (20g ha^{-1}) at four DAS followed by an application of bispyribac sodium (25g ha^{-1}) at 20 DAS.

3.3.9 Plant Protection

Quinalphos (2000 mL ha^{-1}) was applied against leaf folder at 20 DAS and fish jaggery mixture (4%) was used against rice bug at milky stage.

No serious incidence of disease was observed during the crop growth period.

3.3.10 Harvest

The crop was harvested after 105 days of sowing/planting. The net plot area was harvested, threshed, winnowed and grain and straw weight were recorded separately and expressed in kg ha^{-1} on dry weight basis.

3.4 OBSERVATIONS ON PLANT

3.4.1 Growth Parameters

3.4.1.1 *Number of Hills m^{-2}*

Number of hills were counted at 20 DAS / 15 DAT by using a quadrat of size 0.25 m x 0.25 m from the net plot area of each treatment and the average was worked out.

3.4.1.2 *Plant Height*

Plant height was measured from 10 randomly selected plants at 40 and 60 DAS / 25 and 45 DAT and at harvest and expressed in cm. The plant height was measured from the base to the tip of the top most leaf. At harvest, the height was recorded from the base to the tip of the longest panicle.

3.4.1.3 *Tillers m^{-2}*

Number of tillers was counted at 40 and 60 DAS / 25 and 45 DAT and at harvest by using a quadrat of size 0.25 m x 0.25 m from the net plot area of each treatment and the average was worked out.

3.4.1.4 *Leaf Area Index* (LAI)

Leaf length and breadth of the fourth leaf from top were measured from ten randomly selected primary tillers at 40 and 60 DAS / 25 and 45 DAT. Leaf area was then worked out by using the formula suggested by Palanisamy and Gomez (1974).

Leaf area = K (L×B)

K = 0.75 (Yoshida *et al.*, 1976)

L = Leaf length (cm)

B = Maximum breadth of the leaf (cm)

By multiplying the leaf area with number of leaves in a tiller, leaf area tiller^{-1} was obtained and then the LAI was calculated as follows:

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Ground Area}}$$

3.4.1.5 *Root* : *Shoot Ratio*

At 50 per cent flowering, ten hills were randomly selected and uprooted from the sample rows outside the net plot area leaving one border row. The plant samples were initially air dried for a day and later oven dried at 65 ± 5 °C to a constant weight. Then the root : shoot ratio was calculated by separately weighing the root and shoot.

3.4.1.6 *Dry Matter Production (DMP)*

At harvest stage, ten hills were randomly selected and uprooted from the sample rows outside the net plot area leaving one border row. The plant samples were initially air dried for a day and later oven dried at 65 ± 5 °C to constant weight. The total DMP was computed and was expressed in kg ha^{-1}.

3.4.2 Physiological Parameters

3.4.2.1 *Chlorophyll Content*

Total chlorophyll content of the leaves was analyzed at 40 and 60 DAS / 25 and 45 DAT by DMSO (dimethyl sulphoxide) method suggested by Yoshida *et al*. (1976). The first fully opened leaves from the top were selected as index leaves and were removed from the plants sampled for chemical analysis. A weighed quantity of sample (0.5g) was taken and cut into small bits. These bits were put in test tubes and incubated overnight at room temperature, after adding 10 ml DMSO: 80% acetone mixture (1:1 v/v) and the absorbance at 663 and 645 nm were measured in spectrophotometer.

3.4.2 2 *Crop Growth Rate (CGR)*

From outside the net plot area of each treatment plot leaving border rows, five plants were randomly selected at 40 and 60 DAS / 25 and 45 DAT. The plants were uprooted, washed, sun dried for a day and then dried to a constant weight in hot air oven at 65 ±5°C. Crop growth rate was calculated using the formula suggested by Watson (1958).

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{A} \ g\ m^{-2}\ day^{-1}$$

Where W_2 is weight of crop at t_2, W_1 is the weight of crop at stage t_1 and t_2 and t_1 are duration in days between the crop growth stages and A is ground area.

3.4.2.3 ***Relative Growth Rate (RGR)***

As in CGR five plants were randomly uprooted at 40 and 60 DAS / 25 and 45 DAT. The amount of dry matter per unit dry weight of plant per unit time was calculated using the formula suggested by Evans (1972) and expressed as mg g^{-1} day^{-1}

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \text{ mg g}^{-1} \text{ day}^{-1}$$

Where $\log_e W_2$ and $\log_e W_1$ are the logarithmic value of dry weight of crop at t_2 and t_1 respectively and t_2 and t_1 are duration in days between the crop growth stages.

3.4.3 Yield Attributes

3.4.3.1 ***Number of Panicles m^{-2}***

At harvest, productive tillers were counted by using a quadrat of size 0.5 m x 0.5 m at two representative sites inside the net plot area and the mean number was worked out and expressed as panicles m^{-2}.

3.4.3.2 ***Panicle Length***

Ten panicles were randomly selected from each treatment plot and the length was measured from the point of scar to the tip of the panicle, average length was worked out and expressed in cm.

3.4.3.3 ***Weight of Grains Per Panicle***

Ten panicles were randomly selected from each treatment plot, grains were separated from each panicle and the weight was recorded on dry weight basis. The mean value was computed and expressed in g.

3.4.3.4 *Filled Grains Per Panicle*

The filled grains were separated from each panicle, counted and the average number was arrived at.

3.4.3.5 *Panicle Weight*

Ten panicles were collected randomly from each treatment plot, weighed separately and mean weight was worked out and expressed in g.

3.4.3.6 *Sterility Percentage*

From the ten randomly selected panicles, the total number of filled and unfilled grains were counted separately for each panicle and the sterility percentage was worked out using the following formula

$$\text{Sterility percentage} = \frac{\text{Number of unfilled grains per panicle}}{\text{Total number of grains per panicle}} \times 100$$

3.4.3.7 *Thousand Grain Weight*

Thousand grains from each net plot area were drawn at random, dried and weighed at 14 per cent moisture content and expressed in g.

3.4.3.8 *Grain Yield*

The grain harvested from the net plot area was sun dried to 14 per cent moisture content, the grain weight was recorded and expressed in kg ha^{-1}.

3.4.3.9 *Straw Yield*

The straw harvested from each net plot area was dried to constant weight under sunlight for three consecutive days and expressed in kg ha^{-1}.

3.4.3.10 *Harvest Index* (HI)

The harvest index was calculated using the following formula suggested by Donald and Hamblin (1976).

$$\text{Harvest index (HI)} = \frac{\text{Economic Yield}}{\text{Biological Yield}}$$

3.5 OBSERVATION ON WEEDS

3.5.1 Weed Flora Composition

Major weed species that infested the experimental site during the period of experimentation were identified and grouped into grasses, sedges and broad leaved weeds.

3.5.2 Absolute Density of Weeds

Number of weeds recorded from randomly selected quadrate (0.25 m x 0.25 m) at two sites in each plot and the mean value was recorded. The weeds were then categorized into grasses, sedges and broad leaved weeds. The absolute density of grasses, broad leaved weeds and sedges were worked out at 30 and 60 DAS / 15 and 45 DAT.

3.5.3 Weed Dry Weight

Weed dry weight was recorded at 30 and 60 DAS / 15 and 45 DAT by placing a qudrat of size 0.25 m x 0.25 m randomly at two sites in each plot. The uprooted weeds were sundried for one day and then oven dried at 65 ± 5 °C until constant weight was attained and dry weight was recorded.

3.6 CHEMICAL ANALYSIS

3.6.1 Soil Analysis

For initial soil sample analysis, soil samples were drawn from a depth of 15 cm from four different spots in each plot, shade dried, ground and composite samples were prepared by quartering. After the harvest of crop also, composite soil samples were drawn from each treatment plot for the analysis of organic carbon and available N, P, K status.

3.6.1.1 *Organic Carbon*

The composite soil samples prepared were sieved through 0. 2 mm sieve and analyzed for organic carbon by rapid titration method (Walkley and Black, 1934).

3.6.1.2 *Available Nitrogen*

Soil samples were analyzed for available N by alkaline potassium permanganate method (Subbiah and Asija, 1956).

3.6.1.3 *Available Phosphorus*

Available P content of the soil was determined by Dickman and Brays molybdenum blue method using spectrophotometer (Jackson, 1973).

3.6.1.4 *Available Potassium*

Available K content of the soil was determined by extraction with neutral normal ammonium acetate and estimated using flame photometer (Jackson, 1973).

3.6.2 Plant Analysis

3.6.2.1 *Nutrient Content in Plants*

The plant samples at harvest stage were analyzed for total N, P and K content. The grains were analysed separately. The weed samples were analyzed for total N, P and K content at 30 and 60 DAS / 15 and 45 DAT. The samples were initially sun dried for a day and then dried in hot air oven at 65 ± 5 °C to constant weight, ground and used for analysis. The required quantities of samples were weighed out accurately, subjected to acid extraction and N, P and K content were determined.

3.6.2.2 *Total Nitrogen Content*

Total N content was estimated by modified microkjheldal method (Jackson, 1973).

3.6.2.3 *Total Phosphorus Content*

Total P content was estimated by vanadomolybdate phosphoric yellow colour method (Jackson, 1973).

3.6.2.4 *Total Potassium Content*

Total K content was determined using flame photometer (Jackson, 1973).

3.6.3 Nutrient Uptake

The plant samples at harvest stage were analyzed for total N, P and K content. The grains were analysed separately The N, P and K uptake by crop at harvest and weeds at 30 and 60 DAS / 15 and 45 DAT were worked out by multiplying the nutrient content with respective dry weight of plant samples expressed in kg ha^{-1}.

3.7 ECONOMIC ANALYSIS

The economics of cultivation was worked out based on the cost of cultivation and the prevailing market price of the produce.

3.7.1 Net Income

Net income was calculated using the formula

Net income (₹ ha^{-1}) = Gross income - Cost of cultivation

3.7.2 Benefit Cost Ratio (B: C Ratio)

Benefit cost ratio was calculated using the formula

$$\text{B: C Ratio} = \frac{\text{Gross Income}}{\text{Cost of cultivation}}$$

3.8 PEST AND DISEASE INCIDENCE

Serious pest and disease infestation was not observed. Only minor incidence of leaf folder at tillering stage and rice bug at milky stage were noticed

3.9 STATISTICAL ANALYSIS

The experimental data were analyzed statistically by using analysis of variance technique for RBD (Cochran and Cox, 1965) and the significance was tested using F test. The data which required transformation were appropriately transformed and analyzed. Wherever the F values were found significant, critical difference was calculated at five per cent probability level.

Results

4. RESULTS

The results of the field experiment carried out during Kharif 2018 (May to September 2018) at CRS, Balaramapuram, Thiruvanathapuram with the objectives to find out the most cost effective crop establishment technique for upland rice and to assess its impact on growth and yield of rice are presented in this chapter.

4.1 GROWTH ATTRIBUTES

4.1.1 Number of Hills m^{-2}

Data corresponding to the effect of establishment techniques on number of hills m^{-2} at 20 DAS / 15 DAT are given in Table 1.

Establishment techniques significantly influenced the number of hills m^{-2}. Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded the highest number of hills, which was statistically comparable with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). The lowest number of hills were observed in thomba method of planting 20 cm x 10 cm (T_{10}).

4.1.2 Plant Height

Data pertaining to the effect of establishment techniques on plant height at 40 DAS, 60 DAS and at harvest are presented in Table 2.

The plant establishment techniques had significant influence on plant height. At 40 and 60 DAS, broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) produced the tallest plants, but was comparable with all the other establishment techniques except thomba method of planting at 20 cm x 10 cm (T_{10}) at 40 DAS, and at 60 DAS, it was found on par with all treatments except broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8), thomba method of planting at 15 cm x 10 cm (T_9) and thomba method of planting at 20 cm x 10 cm (T_{10}). At harvest, the tallest plants were observed in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and apart from, line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) and thomba method of planting 20 cm x 10 cm (T_{10}), all the other planting techniques were found statistically comparable with it.

4.1.3 Tillers m^{-2}

Data pertaining to the effect of establishment techniques on number of tillers m^{-2} is shown in Table 3.

The plant establishment techniques significantly influenced number of tillers m^{-2}. At 40 DAS and harvest, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) produced higher number of tillers, but on par with broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) at 40 DAS and significantly superior at harvest. Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded higher tiller number at 60 DAS, statistically comparable with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). Thomba method of planting at 20 cm x 10 cm (T_{10}) recorded the lowest number of tillers at all stages.

4.1.4 Leaf Area Index (LAI)

Data related to the effect of establishment techniques on leaf area index is presented in Table 4.

The plant establishment techniques had significant influence on LAI at 40 and 60 DAS. Results revealed that at 40 and 60 DAS, broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) had the highest LAI at 40 DAS and it was on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), broadcasting dry seeds 100 kg ha^{-1} (T_5) and broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) and at 60 DAS it was comparable with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and broadcasting dry seeds 100 kg ha^{-1} (T_5). Thomba method of planting at 20 cm x 10 cm (T_{10}) recorded the lowest LAI both at 40 and 60 DAS.

4.1.5 Root : Shoot Ratio

Data showing the effect of establishment techniques on root:shoot ratio at 50 per cent flowering is presented in Table 5.

The root:shoot ratio was significantly influenced by the different establishment techniques. Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher root : shoot ratio, on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6). Thomba method of planting at 20 cm x 10 cm (T_{10}) recorded the lowest root:shoot ratio.

4.1.6 Dry Matter Production (DMP)

Data indicating the effect of establishment techniques on DMP is represented in Table 6.

Different establishment techniques had significant influence on DMP. At 40 DAS, broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) had the highest comparable DMP with all the treatments except, line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting dry seeds 100 kg ha^{-1}(T_5), thomba method of planting 15 cm x10 cm (T_9) and thomba method of planting 15 cm x10 cm (T_{10}). However DMP at 60 DAS and harvest were higher in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), which was statistically on par with all the other establishment techniques, except line sowing dry seeds 60 kg ha^{-1}(T_1), broadcasting dry seeds 80 kg ha^{-1}(T_3), broadcasting pre-germinated seeds 100 kg ha^{-1}(T_8) and thomba method of planting at 20 cm x 10 cm (T_{10}) at 60 DAS and on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) at harvest. Dry matter production was the lowest in T_{10} (thomba method of planting 20 cm x 10 cm) at all stages of observation.

Table 1. Effect of establishment techniques on number of hills m^{-2}

Treatments	Hills m^{-2}
	20 DAS / 15 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	63.67
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	72.00
T_3: Broadcasting dry seeds 80 kg ha^{-1}	62.33
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	72.67
T_5: Broadcasting dry seeds 100 kg ha^{-1}	61.33
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	79.33
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	68.33
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	67.00
T_9: Thomba method of planting 15 cm x10 cm	60.33
T_{10}: Thomba method of planting 20 cm x10 cm	50.67
SEm (±)	2.82
CD (0.05)	8.528

Table 2. Effect of establishment techniques on plant height, cm

Treatments	Plant height		
	40 DAS/ 25 DAT	60 DAS/ 45 DAT	Harvest
T_1: Line sowing dry seeds 60 kg ha^{-1}	61.17	80.75	94.78
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	63.13	81.12	96.45
T_3: Broadcasting dry seeds 80 kg ha^{-1}	62.80	82.78	96.54
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	61.90	84.42	96.67
T_5: Broadcasting dry seeds 100 kg ha^{-1}	61.10	82.96	96.83
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	65.40	86.35	99.38
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	60.50	79.77	93.95
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	61.63	79.83	95.74
T_9: Thomba method of planting 15 cm x10 cm	59.33	77.09	95.30
T_{10}: Thomba method of planting 20 cm x10 cm	57.60	76.63	90.55
SEm (±)	57.60	76.63	90.55
CD (0.05)	6.780	5.881	4.522

Table 3. Effect of establishment techniques on tillers m^{-2}

Treatments	Number of tillers m^{-2}		
	40 DAS/ 25 DAT	60 DAS/ 45 DAT	Harvest
T_1: Line sowing dry seeds 60 kg ha^{-1}	495.68	534.00	497.00
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	497.63	550.33	508.33
T_3: Broadcasting dry seeds 80 kg ha^{-1}	479.12	542.00	499.00
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	559.76	585.33	562.33
T_5: Broadcasting dry seeds 100 kg ha^{-1}	482.13	557.43	514.00
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	522.33	609.12	535.33
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	454.43	504.00	500.67
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	439.63	458.68	446.68
T_9: Thomba method of planting 15 cm x10 cm	377.00	486.00	502.67
T_{10}: Thomba method of planting 20 cm x10 cm	355.38	421.65	404.33
SEm (±)	12.74	10.16	8.53
CD (0.05)	38.217	30.498	25.587

Table 4. Effect of establishment techniques on leaf area index

Treatments	LAI	
	40 DAS/ 25 DAT	60 DAS/ 45 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	3.38	5.24
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	3.50	5.74
T_3: Broadcasting dry seeds 80 kg ha^{-1}	3.57	5.13
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	3.96	6.26
T_5: Broadcasting dry seeds 100 kg ha^{-1}	3.84	5.88
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	4.03	6.48
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	3.47	5.08
T_8: Broadcasting pre-germinated seeds100 kg ha^{-1}	3.23	5.11
T_9: Thomba method of planting 15 cm x10 cm	3.02	4.38
T_{10}: Thomba method of planting 20 cm x10 cm	2.73	4.02
SEm (±)	0.20	0.25
CD (0.05)	0.585	0.741

Table 5. Effect of establishment techniques on root : shoot ratio

Treatments	Root : shoot ratio (at 50 per cent flowering)
T_1: Line sowing dry seeds 60 kg ha^{-1}	0.16
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	0.22
T_3: Broadcasting dry seeds 80 kg ha^{-1}	0.21
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	0.25
T_5: Broadcasting dry seeds 100 kg ha^{-1}	0.21
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	0.22
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	0.14
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	0.20
T_9: Thomba method of planting 15 cm x10 cm	0.19
T_{10}: Thomba method of planting 20 cm x10 cm	0.19
SEm (±)	0.01
CD (0.05)	0.037

Table 6. Effect of establishment techniques on dry matter production, kg ha^{-1}

Treatments	Dry matter production		
	40 DAS/ 25 DAT	60 DAS/ 45 DAT	Harvest
T_1: Line sowing dry seeds 60 kg ha^{-1}	1304.95	3132.13	7536.77
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	1575.08	3536.43	7798.93
T_3: Broadcasting dry seeds 80 kg ha^{-1}	1436.77	3193.20	7551.63
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	1347.90	3868.17	8366.47
T_5: Broadcasting dry seeds 100 kg ha^{-1}	1292.63	3593.50	7601.93
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	1643.75	3743.30	7869.23
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	1369.80	3461.07	7420.40
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	1399.51	2975.87	6926.40
T_9: Thomba method of planting 15 cm x10 cm	1068.82	3359.00	7599.10
T_{10}: Thomba method of planting 20 cm x10 cm	1067.21	2817.47	5716.87
SEm (±)	102.47	178.40	192.31
CD (0.05)	307.419	535.206	576.940

4.2 PHYSIOLOGICAL PARAMETERS

4.2.1 Crop Growth Rate (CGR)

Data relating to the effect of establishment techniques on CGR is given in Table 7.

Among the establishment techniques, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher crop growth rate at 40 to 60 DAS and 60 DAS to harvest which was on par with thomba method of planting 15 cm x10 cm (T_9) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) at 40 to 60 DAS and with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) at harvest. The CGR value was found the lowest in thomba method of planting 20 cm x10 cm (T_{10}) at both the periods.

4.2.2 Relative Growth Rate (RGR)

Data remarking the effect of establishment techniques on RGR is depicted in Table 8.

Relative growth rate during 40 to 60 DAS was the highest in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and on par with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), while RGR was higher during 60 DAS to harvest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and apart from broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), thomba method of planting 15 cm x10 cm (T_9) and thomba method of planting 20 cm x10 cm (T_{10}), it was statistically comparable with all the other establishment techniques.

4.2.3 Total Chlorophyll Content

Data regarding the effect of establishment techniques on total chlorophyll content is presented in Table 9.

The effect of plant establishment techniques on total chlorophyll content was significant and at 40 DAS it was found higher in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), comparable with line sowing dry seeds 60 kg ha^{-1} (T_1), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). At 60 DAS, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher chlorophyll content which was on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and thomba method of planting at 15 cm x10 cm (T_9).

4.3 OBSERVATION ON WEEDS

4.3.1 Weed Flora Composition

Weed species present in the experimental field during the study were collected, identified and categorized into grasses, sedges and broad leaved weeds. The results on floristic composition are detailed in Table 10.

4.3.2 Absolute density of grasses, sedges and broad leaved weeds

Data on absolute density of grasses, sedges and broad leaved weeds are depicted in Table 11.

The results on absolute density of grasses at 30 DAS showed the lowest value in T_6, comparable with T_4 and T_8, whereas at 60 DAS, it was the least in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), on par with T_6. The absolute density of broad leaved weeds at 30 and 60 DAS was the lowest in T_4, comparable with T_6. The absolute density of sedges at 30 DAS was found lower and comparable in treatments T_2, T_4, T_6, T_7 and T_8. At 60 DAS, all the establishment techniques recorded significantly lower and on par values except T_9 and T_{10}.

4.3.3 Weed Dry Weight

Data pertaining to the effect of establishment techniques on weed dry weight is shown in Table 12.

Table 8. Effect of establishment techniques on crop growth rate, g m^{-2} day^{-1}

Treatments	CGR	
	40 to 60 DAS / 25 to 45 DAT	60 DAS to harvest / 45 DAT to harvest
T_1: Line sowing dry seeds 60 kg ha^{-1}	9.73	10.11
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	11.62	11.04
T_3: Broadcasting dry seeds 80 kg ha^{-1}	10.90	10.53
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	13.50	11.42
T_5: Broadcasting dry seeds 100 kg ha^{-1}	11.66	9.88
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	12.78	10.76
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	10.25	9.56
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	8.76	9.86
T_9: Thomba method of planting 15cm x10 cm	12.73	10.47
T_{10}: Thomba method of planting 20cm x10 cm	9.72	7.16
SEm (±)	0.29	1.77
CD (0.05)	0.859	0.593

Table 9. Effect of establishment techniques on relative growth rate, mg g^{-1} day^{-1}

Treatments	RGR	
	40 to 60 DAS / 25 to 45 DAT	60 DAS to harvest / 45 DAT to harvest
T_1: Line sowing dry seeds 60 kg ha^{-1}	18.46	8.34
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	20.46	8.09
T_3: Broadcasting dry seeds 80 kg ha^{-1}	20.04	6.86
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	20.51	8.70
T_5: Broadcasting dry seeds 100 kg ha^{-1}	18.05	7.78
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	22.17	8.08
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	19.09	7.35
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	16.49	7.75
T_9: Thomba method of planting 15cm x10 cm	19.78	7.14
T_{10}: Thomba method of planting 20cm x10 cm	19.07	6.83
SEm (±)	0.56	0.39
CD (0.05)	1.168	1.174

Table 10. Effect of establishment techniques on total chlorophyll content, mg g^{-1}

Treatments	Total chlorophyll	
	40 DAS / 25 DAT	60 DAS / 45 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	2.91	3.49
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	2.99	4.84
T_3: Broadcasting dry seeds 80 kg ha^{-1}	2.86	4.06
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	3.13	4.88
T_5: Broadcasting dry seeds 100 kg ha^{-1}	2.63	3.73
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	3.49	4.28
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	2.29	2.53
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	2.64	3.33
T_9: Thomba method of planting 15 cm x10 cm	2.91	4.06
T_{10}: Thomba method of planting 20 cm x10 cm	2.11	3.53
SEm (±)	0.19	0.28
CD (0.05)	0.581	0.848

Weed dry weight at 30 DAS recorded minimum in line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and was comparable with all the other establishment techniques except, line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), thomba method of planting at 15 x10 cm (T_9) and thomba method of planting at 20 cm x 10 cm (T_{10}). The highest weed dry weight was observed in thomba method of planting at 20 cm x 10 cm (T_{10}). While at 60 DAS, the least weed dry weight was observed in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) which was statistically on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) and thomba method of planting at 15 cm x 10 cm (T_9). Broadcasting dry seeds 80 kg ha^{-1} (T_3) recoded the highest weed dry weight at 60 DAS.

4.4 YIELD ATTRIBUTES

4.4.1 Days to 50 per cent flowering

Data regarding the effect of establishment techniques on days to 50 per cent flowering is depicted in Table 14.a

The period for 50 per cent flowering was the shortest and significant in line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) when compared to all other planting techniques. The longest period for 50 per cent flowering was observed in thomba method of planting at 20 cm x 10 cm (T_{10}), on par with thomba method of planting at 15 cm x 10 cm (T_9).

4.4.2 Number of Panicles m^{-2}

Data related to number of panicles m^{-2} is shown in Table 14.a

Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) produced the highest number of panicles and was comparable with line sowing dry seeds 60 kg ha^{-1} (T_1), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and thomba method of

Table 11. Floristic composition of weeds observed in the experimental field

Common Name	Scientific Name	Family
GRASSES		
Crow footgrass	*Dactyloctenium aegypticum*	Poaceae
East Indian bristlegrass	*Setaria barbata*	Poaceae
Goose grass	*Eleusine indica*	Poaceae
Bermuda grass	*Cynodon dactylon*	Poaceae
Southern crabgrass	*Digitaria ciliaris*	Poaceae
SEDGES		
Nutsedge	*Cyperus rotundus*	Cyperaceae
BROAD LEAVED WEEDS		
Touch-me-not plant	*Mimosa pudica*	Fabaceae
Stone breaker	*Phyllanthus niruri*	Phyllanthaceae
Sessile joy weed	*Alternanthera sessilis*	Amaranthaceae
Indian sarasaparilla	*Hemidesmus indicus*	Apocyanaceae

Table 12. Effect of establishment techniques on absolute density of weeds, number m^{-2}

Treatments	Grasses		Sedges		Broad leaved weeds	
	30 DAS / 15 DAT	60 DAS / 45 DAT	30 DAS / 15 DAT	60 DAS / 45 DAT	30 DAS / 15 DAT	60 DAS / 45 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	3.95 (14.66)	2.51 (5.33)	2.76 (6.67)	1.00 (0.00)	3.60 (12.00)	2.24 (4.00)
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	3.20 (9.33)	2.49 (5.33)	2.24 (4.00)	1.00 (0.00)	2.99 (8.00)	2.04 (4.00)
T_3: Broadcasting dry seeds 80 kg ha^{-1}	3.78 (13.33)	4.12 (16.00)	2.76 (6.67)	1.00 (0.00)	4.04 (14.67)	2.14 (4.00)
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	2.73 (6.67)	1.52 (1.33)	2.24 (4.00)	1.00 (0.00)	2.24 (4.00)	1.45 (1.33)
T_5: Broadcasting dry seeds 100 kg ha^{-1}	3.21 (9.33)	2.50 (5.33)	2.76 (6.67)	1.00 (0.00)	3.00 (8.00)	2.24 (4.00)
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	2.49 (5.33)	1.90 (2.67)	2.56 (6.56)	1.00 (0.00)	2.42 (5.30)	1.90 (2.66)
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	3.78 (13.33)	2.24 (4.00)	2.56 (6.56)	1.00 (0.00)	3.41 (10.66)	2.49 (5.33)
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	2.75 (6.67)	2.75 (6.66)	2.76 (6.67)	1.00 (0.00)	3.21 (9.33)	2.49 (5.33)
T_9: Thomba method of planting 15 cm x10 cm	3.61 (12.00)	2.49 (5.33)	2.24 (4.00)	1.52 (0.00)	2.51 (2.49)	1.91 (2.67)
T_{10}: Thomba method of planting 20 cm x10 cm	3.60 (12.00)	2.745 (6.66)	3.00 (8.00)	1.52 (0.00)	2.99 (8.00)	2.10 (4.00)
SEm(±)	0.20	0.14	0.13	0.05	0.13	0.15
CD (0.05)	0.596	0.431	0.399	0.146	0.374	0.454

The figures are subjected to square root transformation $\sqrt{(x+1)}$ and transformed values are given in parenthesis

Table 13. Effect of establishment techniques on weed dry weight, g m^{-2}

Treatments	Weed dry weight	
	30 DAS / 15 DAT	60 DAS / 45 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	4.37	3.88
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	2.45	2.34
T_3: Broadcasting dry seeds 80 kg ha^{-1}	3.21	3.92
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	2.65	1.92
T_5: Broadcasting dry seeds 100 kg ha^{-1}	2.84	3.79
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	2.61	2.56
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	3.75	2.50
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	3.06	3.49
T_9: Thomba method of planting 15cm x10 cm	3.28	2.36
T_{10}: Thomba method of planting 20 cm x10 cm	4.15	3.55
SEm (±)	0.28	0.31
CD (0.05)	0.824	0.992

planting at 15 cm x10 cm (T_9). The number of panicles were the lowest in thomba method of planting at 20 cm x10 cm (T_{10}).

4.4.3 Panicle Length

Data pertaining to the effect of establishment techniques on panicle length is detailed in Table 14.a.

The panicle length was found to be significantly different among the treatments. Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) produced the longest panicles and was on par with all the other planting techniques apart from broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8) and thomba method of planting at 20 cm x10 cm (T_{10}).

4.4.4 Panicle Weight

Data on the effect of establishment techniques on panicle weight is shown in Table 14.a.

Broadcasting hydroprimed seeds 80 kg ha^{-1}(T_4) reported the highest panicle weight among the different treatments and it was comparable with broadcasting dry seeds 80 kg ha^{-1} (T_3) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6). Thomba method of planting at 20 cm × 10 cm (T_{10}) recorded the lowest panicle weight.

4.4.5 Filled Grains Per Panicle

Table 14.b shows the effect of establishment techniques on number of filled grains per panicle.

The number of filled grains per panicle was significantly influenced by the establishment techniques. The observations recorded the highest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), comparable with broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), while the lowest in thomba method of planting at 20 cm × 10 cm (T_{10}).

Table 14.a. Effect of establishment techniques on yield attributes

Treatments	Days to 50 per cent flowering	No. of panicles m^{-2}	Panicle length (cm)	Panicle weight (g)
T_1: Line sowing dry seeds 60 kg ha^{-1}	80	409.30	23.87	2.46
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	74	405.30	23.10	2.52
T_3: Broadcasting dry seeds 80 kg ha^{-1}	82	372.00	23.87	2.63
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	77	420.00	24.39	2.78
T_5: Broadcasting dry seeds 100 kg ha^{-1}	83	392.00	24.02	2.54
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	79	397.12	24.17	2.73
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	84	364.00	21.86	2.45
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	85	368.70	22.83	2.41
T_9: Thomba method of planting at 15 cm x10 cm	87	390.70	23.40	2.51
T_{10}: Thomba method of planting at 20 cm x10 cm	88	342.70	21.30	2.36
SEm (±)	0.6	10.13	0.47	0.06
CD (0.05)	1.3	41.390	1.406	0.192

4.4.6 Sterility Percentage

Data in Table 14.b revealed the significant influence of establishment techniques on sterility percentage.

The sterility percentage was the lowest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) which was statistically on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), whereas thomba method of planting at 20 cm × 10 cm (T_{10}) recorded the highest sterility percentage.

4.4.7 Thousand Grain Weight

Data on thousand grain weight presented in Table 14.b revealed that establishment techniques had no significant influence on thousand grain weight.

4.4.8 Grain Yield

The influence of establishment techniques on grain yield is depicted in Table 15.

The planting techniques had significant influence on grain yield and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded the highest grain yield, closely followed by line sowing hydroprimed seeds 60 kg ha^{-1} (T_2).These two treatments were statistically comparable with line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) and thomba method of planting at 15 cm × 10 cm (T_9). The grain yield was the lowest in thomba method of planting at 20 cm × 10 cm (T_{10}).

4.4.9 Straw Yield

The straw yield data in Table 15 revealed the superiority of broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) over other treatments and the inferiority of thomba method of planting at a spacing of 20 cm × 10 cm (T_{10}) in reflecting straw yield.

4.4.10 Harvest Index

Table 15 depicting the data on harvest index revealed the non significance of establishment techniques on harvest index.

4.5 NUTRIENT UPTAKE BY CROP

The influence of establishment techniques on N, P and K uptake by crop at harvest stage is presented in Table 16.

4.5.1 N uptake

The results on N uptake by the crop among the different establishment techniques recorded the highest value in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), statistically comparable with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting dry seeds 100 kg ha^{-1} (T_5). The lowest N uptake was observed in thomba method of planting at 20 cm × 10 cm (T_{10}).

Table 14.b. Effect of establishment techniques on yield attributes

Treatments	No. of filled grains per panicle	Sterility percentage	1000 grain weight (g)
T_1: Line sowing dry seeds 60 kg ha^{-1}	96.73	17.92	25.35
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	102.27	12.64	25.33
T_3: Broadcasting dry seeds 80 kg ha^{-1}	102.00	11.38	25.85
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	113.60	10.48	26.15
T_5: Broadcasting dry seeds 100 kg ha^{-1}	99.47	17.38	25.21
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	108.80	11.37	2663
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	97.80	17.56	25.21
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	99.53	16.38	24.95
T_9: Thomba method of planting 15 cm x10 cm	98.27	16.75	25.61
T_{10}: Thomba method of planting 20 cm x10 cm	81.67	18.88	24.73
SEm (±)	3.51	1.04	0.92
CD (0.05)	10.530	3.126	NS

NS: Not significant

Table 15. Effect of establishment techniques on grain yield, straw yield and harvest index

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI
T_1: Line sowing dry seeds 60 kg ha^{-1}	3671.7	3865.9	0.48
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	3889.0	3912.6	0.49
T_3: Broadcasting dry seeds 80 kg ha^{-1}	3675.7	3875.6	0.48
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	3900.7	3968.9	0.49
T_5: Broadcasting dry seeds 100 kg ha^{-1}	3786.0	3941.8	0.49
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	3871.7	4494.8	0.46
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	3606.3	3814.1	0.48
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	3392.3	3543.7	0.49
T_9: Thomba method of planting 15 cm x10 cm	3593.7	3782.4	0.48
T_{10}: Thomba method of planting 20 cm x10 cm	3023.7	3273.9	0.46
SEm (±)	109.8	105.7	0.01
CD (0.05)	329.01	316.49	NS

NS: Not significant

4.5.2 P uptake

Phosphorous uptake by the crop at harvest was significant between the different establishment techniques. Even though, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) showed the highest uptake data, it was on par with line sowing hydroprimed seeds 60 kg ha^{-1}(T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1}(T_5) and broadcasting hydroprimed seeds 100 kg ha^{-1}(T_6). Thomba method of planting at 20 cm × 10 cm (T_{10}) recorded the lowest P uptake.

4.5.3 K uptake

The uptake of K was also found significant among the treatments. Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded the highest value followed by broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and thomba method of planting at 15 cm × 10 cm (T_9), respectively and were also on par.

4.6 NUTRIENT UPTAKE BY WEEDS

Data pertaining to the effect of establishment techniques on nutrient uptake by weeds at 30 and 60 DAS / 15 and 45 DAT are given in Table 17.

4.6.1 N uptake

The uptake of N by weeds was found significant among treatments at 30 DAS and was found the lowest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), on par with broadcasting dry seeds 80 kg ha^{-1} (T_3) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6).

4.6.2 P uptake

The P uptake by weeds was not significant at any of the growth stages.

4.6.3 K uptake

Similar to P, establishment techniques did not show any significant effect on K uptake by weeds.

4.7 SOIL NUTRIENT STATUS

The post harvest soil analysis data on organic carbon and available NPK content are presented in Table 18.

4.7.1 Organic Carbon Content of Soil

Establishment techniques had significant effect on organic carbon content of soil. The data revealed that organic carbon content was the highest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), closely followed by broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1} (T_5) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) which were also on par. The organic carbon content was the lowest in line sowing dry seeds 60 kg ha^{-1} (T_1).

4.7.2 Available N Status of Soil

Available N status of the soil was found significantly influenced by establishment techniques and was the highest in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), but comparable with line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting dry seeds 80 kg ha^{-1} (T_3) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4).

4.7.3 Available P Status of Soil

Broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8) showed the highest P status and was on par with all other planting techniques except broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), thomba method of planting at 15 cm × 10 cm (T_9) and thomba method of planting at 20 cm × 10 cm (T_{10}).

4.7.3 Available K Status of Soil

A significant difference was observed among the planting techniques in which broadcasting dry seeds 80 kg ha^{-1} (T_3) recorded a higher value,

Table 16. Effect of establishment techniques on N, P and K uptake, kg ha^{-1}

Treatments	Uptake at harvest		
	N	P	K
T_1: Line sowing dry seeds 60 kg ha^{-1}	129.41	18.66	83.44
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	132.12	21.87	84.02
T_3: Broadcasting dry seeds 80 kg ha^{-1}	129.41	20.70	88.91
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	137.85	22.00	94.62
T_5: Broadcasting dry seeds 100 kg ha^{-1}	130.81	20.48	89.88
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	148.35	21.96	91.92
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	128.98	18.94	83.86
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	116.89	18.90	83.68
T_9: Thomba method of planting 15 cm x10 cm	124.29	18.03	89.21
T_{10}: Thomba method of planting 20 cm x10 cm	101.28	17.05	79.02
SEm (±)	5.72	0.53	2.31
CD (0.05)	18.932	1.573	6.861

Table 17. Effect of establishment techniques on N, P and K uptake by weeds, kg ha^{-1}

Treatments	Uptake					
	N		P		K	
	30 DAS / 15 DAT	60 DAS / 45 DAT	30 DAS / 15 DAT	60 DAS / 45 DAT	30 DAS / 15 DAT	60 DAS / 45 DAT
T_1: Line sowing dry seeds 60 kg ha^{-1}	0.67	0.76	0.44	0.60	0.43	0.40
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	0.48	0.56	0.12	0.12	0.48	0.38
T_3: Broadcasting dry seeds 80 kg ha^{-1}	0.57	0.72	0.10	0.70	0.40	0.30
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	0.43	0.50	0.13	0.10	0.33	0.39
T_5: Broadcasting dry seeds 100 kg ha^{-1}	0.59	0.59	0.18	0.34	0.45	0.43
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	0.48	0.55	0.10	0.14	0.38	0.39
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	0.59	0.66	0.56	0.40	0.51	0.33
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	0.58	0.58	0.55	0.60	0.45	0.25
T_9: Thomba method of planting 15 cm x 10 cm	0.52	0.68	0.38	0.70	0.55	0.29
T_{10}: Thomba method of planting 20 cm x 10 cm	0.65	1.93	0.47	0.71	0.56	0.36
SEm (±)	0.02	0.05	0.02	0.04	0.01	0.03
CD (0.05)	0.057	NS	NS	NS	NS	NS

NS: Not significant

Table 18. Effect of establishment techniques on organic carbon content and available N, P and K status of soil after the experiment

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1: Line sowing dry seeds 60 kg ha^{-1}	0.86	367.96	51.25	53.67
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	0.95	351.23	52.01	62.59
T_3: Broadcasting dry seeds 80 kg ha^{-1}	1.10	374.32	52.94	62.62
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	1.26	367.96	45.73	58.90
T_5: Broadcasting dry seeds 100 kg ha^{-1}	1.17	351.23	62.43	59.54
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	1.11	376.32	53.60	59.55
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	1.07	359.60	57.12	59.02
T_8: Broadcasting pre-germinated seeds 100 kg	0.94	354.68	61.28	58.52
T_9: Thomba method of planting 15 cm x10 cm	0.94	334.51	48.73	56.20
T_{10}: Thomba method of planting 20 cm x10 cm	0.87	359.26	31.30	45.75
SEm (±)	0.06	4.62	4.22	1.57
CD (0.05)	0.178	13.890	12.538	4.743

comparable with all other establishment techniques except line sowing dry seeds 60 kg ha^{-1} (T_1), thomba method of planting at 15 cm × 10 cm (T_9) and thomba method of planting at 20 cm × 10 cm (T_{10}).

4.8 ECONOMICS

4.8.1 Net Income

Data pertaining to the effect of establishment techniques on net income are depicted in Table 19.

Establishment techniques significantly influenced the net income. Out of the various establishment techniques practised, the net income reported was the highest in T_4 (broadcasting hydroprimed seeds 80 kg ha^{-1}) and was found to be on par with T_2 (line sowing hydroprimed seeds 60 kg ha^{-1}), T_3 (broadcasting dry seeds 80 kg ha^{-1}), T_5 (broadcasting dry seeds 100 kg ha^{-1}), T_6 (broadcasting hydroprimed seeds 100 kg ha^{-1}) and T_7 (broadcasting pre-germinated seeds 80 kg ha^{-1}).

4.8.2 **B : C Ratio**

Data related to the effect of establishment techniques on B : C ratio is given in Table 21.

The B:C ratio was also significantly influenced by the establishment techniques. The results indicated that the highest B:C ratio of 1.72 recorded in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) was comparable with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7). Thomba method of planting at 20 cm x 10 cm (T_{10}) recorded the lowest net income and B : C ratio..

Table 19. Effect of establishment techniques on economics of upland rice.

Treatments	Net returns (₹ ha^{-1})	B:C Ratio
T_1: Line sowing dry seeds 60 kg ha^{-1}	33126	1.55
T_2: Line sowing hydroprimed seeds 60 kg ha^{-1}	37723	1.62
T_3: Broadcasting dry seeds 80 kg ha^{-1}	36164	1.65
T_4: Broadcasting hydroprimed seeds 80 kg ha^{-1}	42214	1.72
T_5: Broadcasting dry seeds 100 kg ha^{-1}	37976	1.66
T_6: Broadcasting hydroprimed seeds 100 kg ha^{-1}	41687	1.70
T_7: Broadcasting pre-germinated seeds 80 kg ha^{-1}	35017	1.61
T_8: Broadcasting pre-germinated seeds 100 kg ha^{-1}	28636	1.50
T_9: Thomba method of planting 15 cm x10 cm	27736	1.44
T_{10}: Thomba method of planting 20 cm x10 cm	14723	1.24
SEm (±)	2684	0.03
CD (0.05)	8036.2	0.131

Discussion

5. DISCUSSION

During the course of field experiment entitled, "Standardization of crop establishment technique for upland rice (*Oryza sativa* L.) in coconut garden" many significant variations were noted due to the treatments constituting the experiment. In this chapter, efforts have been made to assign reasons responsible for such variation that occurred due to different treatments.

5.1 EFFECT OF ESTABLISHMENT TECHNIQUES, SEED PRIMING AND SEED RATE ON GROWTH PARAMETERS

The growth parameters, *viz*., number of hills m^{-2} (20 DAS/15 DAT), plant height (40 and 60 DAS / 25 and 45 DAT and harvest), number of tillers m^{-2} (40 and 60 DAS / 25 and 45 DAT and harvest), LAI (40 and 60 DAS / 25 and 45 DAT), root : shoot ratio (at 50 per cent flowering) and DMP (40 and 60 DAS / 25 and 45 DAT and harvest) were significantly influenced by establishment techniques, seed priming and seed rate.

The data on number of hills m^{-2} (Table. 2) revealed that it was the highest in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). A considerable increase in number of hills in hydropriming seed treatments was due to the effect of hydropriming on different aspects of seed germination and emergence. Hydropriming treatments improved germination percentage and the seed vigour index which appeared to be related to earlier and uniform emergence and subsequent seedling growth. The seed water content absorbed during this period was crucial for initiating the chain of biochemical events required for early synchronised germination in primed seeds which was evident by improved membrane permeability, high activity of catalase and more integrated chloroplast and mitochondria in primed seeds. Shukla *et al*. (2008) reported that seed priming is a co-ordinately regulated mechanism for controlling germination capacity of seeds by modifying the permeability characteristics of biological membranes and enzyme activity. Khaliq *et al*. (2015) reported an enhanced activity of enzymatic antioxidants like superoxide dismutase, peroxidase and glutathione peroxidase in primed seeds by which lipid peroxidation activity decreased during germination and caused accelerated germination and increased the percentage resulting in better and earlier establishment of seedlings.

Broadcasting hydroprimed seeds 80 and 100 kg ha^{-1} each (T_4 and T_6) recorded higher number of tillers (Fig.2). At 40 and 60 DAS, a marked increase in the number of tillers m^{-2} was noted among all the treatments, but a reduction in tiller number was observed in all the establishment techniques at harvest stage. Suman (2018) reported that this reduction was due to the fact that higher tillers m^{-2} increased the plant density which led to increased competition among the plants for resources *viz.*, sunlight, nutrients and water. Increased crop competition for the resources resulted in the deficiency of nutrients which led to tiller abortion. These results were in conformity with the findings of Nurhasanah *et al.* (2017) who reported that excessive tillering may lead to tiller abortion and reduced grain yield.

Plant height was significantly influenced by establishment techniques and broadcasting hydroprimed seeds (T_4 and T_6) recorded taller plants at all stages and this might be due to the early, uniform and vigorous seedlings that gave a stronger and energetic start to the plants resulting in good plant growth. In rice seeds, the metabolic process related to α-amylase activity is initiated by water absorption during seed priming and is preserved in the seed while drying after priming (Ando and Kobata, 2002). The carbohydrate in the seed is thus ready to be used for cell elongation and an increased growth of rice plants is observed due to the enhanced activity of α-amylase.

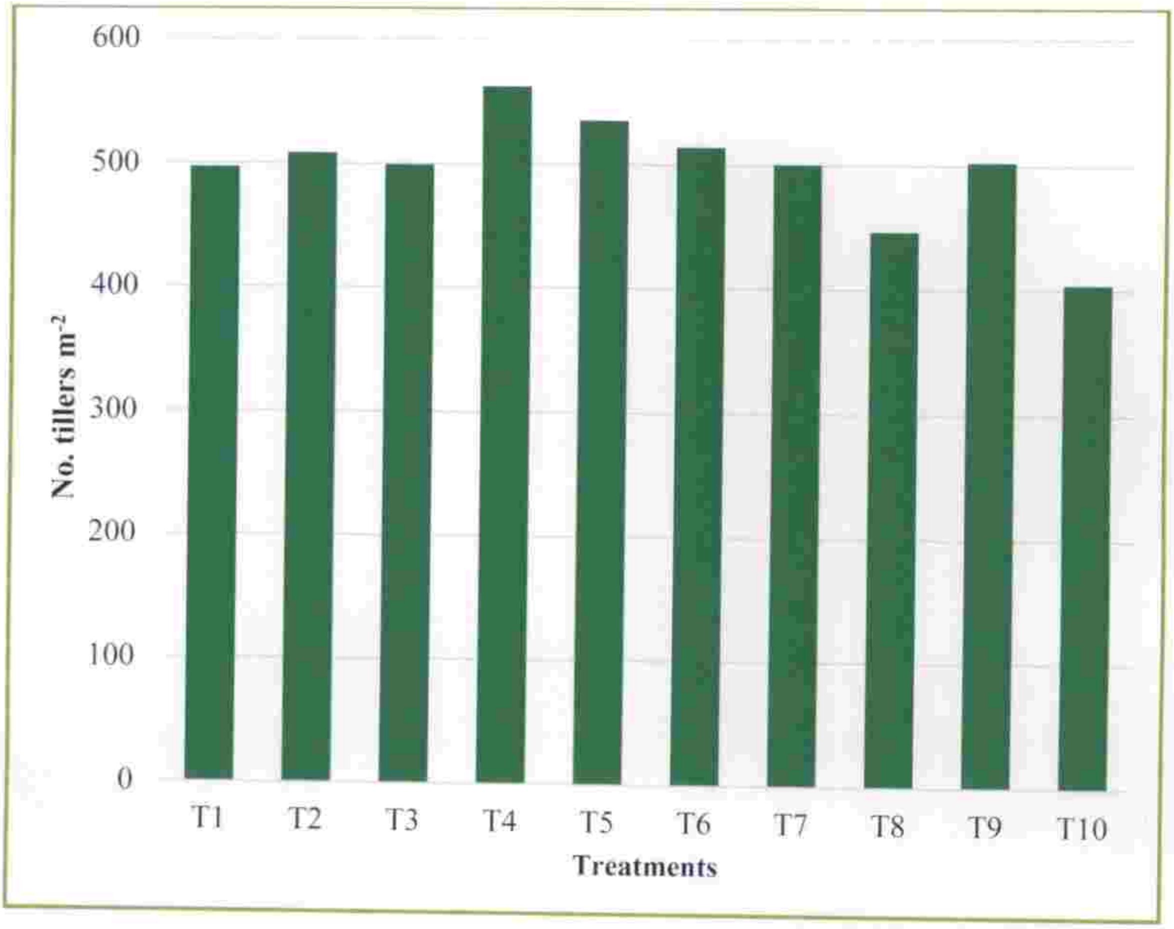

Fig.3.Effect of establishment techniques on no. of tillers m^{-2}

Establishment techniques had significant effect on LAI and root : shoot ratio and the highest values for LAI and root:shoot ratio were observed in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) respectively. Mahajan *et al*. (2011) revealed that an improved root and shoot length was imparted in primed seeds due to increased cell division within the apical meristem. Hydro priming enhanced the vigour of seedlings which accelerated the leaf development resulting in the production of higher number of leaves with larger leaf area. This was similar to the findings of Thiyagarajan *et al.* (2002), who reported that an increase in tiller production might have contributed to a higher photosynthetic rate and an increased LAI. Kant *et al.* (2006) reported that, seed priming with water, salts and growth regulator resulted in more tillers, higher dry matter in leaves, stem and reproductive parts and better grain yield of wheat.

Dry matter production at harvest is an important growth attribute and was observed the highest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6). Harris *et al*. (1999) reported that primed crops emerge faster and more completely, produce more vigorous seedlings, flower and mature earlier and yield better than non-primed crops.

Farooq *et al.* (2006) observed that broadcasting seeds at a higher seed rate increased the plant population which also contributed for the higher total DMP at harvest and also for rice sown in aerated soils, seed priming enhances seedling emergence, grain quality and yield. The lowest DMP was observed with thomba method of planting 20 cm x 10 cm (T_{10}) at all stages of observation

Kumar (2002) from PAU reported that DSR produced significantly higher dry matter than TPR at all stages of growth and at maturity which was due to more plant population per unit area compared to TPR.

The production of vigorous seedlings, improved vegetative and reproductive growth as evidenced by taller plants, more number of hills and tillers, superior LAI indicating larger leaf area and high root : shoot ratio leading to higher nutrient uptake might have resulted in a rapid growth among hydroprimed treatments leading to better accumulation of dry matter at harvest. Seed priming tools have the potential to improve emergence and stand establishment under a wide range of field conditions (Phill, 1995).

5.2 EFFECT OF ESTABLISHMENT TECHNIQUES, SEED PRIMING AND SEED RATE ON PHYSIOLOGICAL PARAMETERS

The physiological parameters, *viz*., CGR (40 and 60 DAS / 25 and 45 DAT), RGR (40 and 60 DAS / 25 and 45 DAT) and total chlorophyll content (40 and 60 DAS / 25 and 45 DAT) were influenced significantly by the establishment techniques. Total chlorophyll content at 60 DAS was found to be higher than the chlorophyll content at 40 DAS among all the treatments.

Primed seeds after planting germinated quicker and better with uniform growth pattern. In fact, the primed seeds extend their root systems with better water and nutrient absorption resulting in larger photosynthetic production of green areas compared to untreated seeds (Duman, 2006). The higher chlorophyll content observed in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) might be due to the higher photosynthetic area as clear from the data on tillers m^{-2} and LAI. Samreen *et al*. (2013) pointed out that higher leaf area resulting from the increase in length and breadth of leaf increases the chlorophyll production and this might be the reason for the higher chlorophyll content at 60 DAS compared to 40 DAS. Seed priming in plants increased the total chlorophyll content and the rate of photosynthesis and ultimately improved the biomass and yield (Mohajeri *et al*., 2017).

Crop growth rate, the gain in weight of a community of plants on a unit of land in a unit time, is used extensively in growth analysis of field crops. CGR gives the efficiency of the complete crop over a specific soil area and is measured as mass increase in crop biomass, per unit ground area per unit time. RGR is a major factor to determine plant growth behaviour in community or sole. RGR expresses the dry weight increase in a time interval in relation to the initial weight. The RGR does not imply a constant growth rate during a particular time frame.

Among the establishment techniques, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher crop growth rate during 40 to 60 DAS and 60 DAS to harvest. Relative growth rate at 40 to 60 DAS was the highest in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and on par with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), while during 60 DAS to harvest, RGR was the highest in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). These results are in line with Basra *et al.* (2003) who found higher CGR for osmoprimed seed for 8 h. They further reported that CGR was greater for primed seed sown fresh or after storage as compared to unprimed seed. Similarly, Zhao *et al.* (2007) reported that pre-soaking seeds before sowing slightly enhanced vegetative crop growth.The improved CGR and RGR in primed direct sown rice might be due to improved efficiency of plants in the production and partitioning of the photosynthates to the developing reproductive parts (Ashraf and Fooland, 2005). Reduced time for emergence to heading and from heading to maturity days among the primed seeds also seemed to improve the physiological characters. Higher LAI improved the chlorophyll content increasing the photosynthetic rate leading to an increased biomass production. This all together caused an increase in plant CGR and RGR values observed.

5.3 EFFECT OF ESTABLISHMENT TECHNIQUES, SEED PRIMING AND SEED RATE ON YIELD ATTRIBUTES AND YIELD

The yield attributes such as days to 50 per cent flowering, number of panicles m^{-2}, panicle length, panicle weight, number of filled grains per panicle and sterility percentage were influenced significantly by establishment techniques, seed priming and seed rate.

The period for 50 per cent flowering was the shortest in line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) (74 days) followed by broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) (78 days). The treatments recorded early flowering and shorter maturity days owing to their better crop establishment and uniform emergence imparted by seed priming. The uniform establishment along with an increased plant density per unit area triggered a quicker reproductive phase response among the plants which also hastened flowering in plants. The longest period for 50 per cent flowering was observed in thomba method of transplanting at 20 cm x10 cm (T_{10}) (88 days), agreeing with IRRI (2008) study reports that direct seeded rice matures seven to ten days earlier than transplanted rice.

The better establishment in primed seeds along with the other benefits like better drought tolerance, better weed competition, early flowering resulted in reduced time to maturity and higher grain yield (Kaur *et al.*, 2005).

The better expression of yield attributes in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) might be due to the increased number of tillers, chlorophyll content and an improved root : shoot ratio in T_4 as a result of hydropriming and broadcasting with a higher seed rate. Hydroprimed treatments resulted in increased number of panicles m^{-2} owing to their healthier and more vigorous seedlings as indicated by an improved leaf area index and photosynthate assimilation. Venkateswaralu (1977) reported that direct-seeded rice gave significantly more productive tiller m^{-2} than transplanted rice, possibly due to greater plant population rather than more tillers per plant.

The results pertaining to sterility percentage pointed out the lowest value in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). The improved nutrients, photoassimilates and moisture supply in plants arising from primed seeds lead to lower number of sterile spikelets in direct seeded rice (Thakuria and Chaudary, 1995).

Poor performance of pre-germinated grains in delayed and erratic emergence of seedlings and subsequently poor plant performance were due to the inability of these grains to utilize germination metabolites optimally (Farooq *et al.*, 2006). The protruded radicle in pre-germinated seeds could not easily penetrate the unpuddled soil and also the seeds were buried ineffectively in the soil which also led to their reduced performance.

Establishment techniques did not make any significant difference in thousand grain weight as it is a genetic character.

The better production of yield attributes particularly number of panicles m^{-2} and filled grains per panicle resulting from the better expression of growth attributes like number of tillers m^{-2} and a better availability and uptake of nutrients might be the reasons for an increased grain yield in treatment T_4 (broadcasting hydroprimed seeds 80 kg ha^{-1}) (Fig.4) . Du and Tuong (2002) concluded that when rice is seeded in very dry soil (near wilting point), priming increased plant density, final tiller number and grain yield. In drought prone areas, seed priming can reduce the need for using high seed rate.

Budhar and Tamilselvan (1990) reported that direct-seeded rice was found advantageous in securing more value of yield attributes, viz., number of panicles m^{-2}, number of filled grains $panicle^{-1}$ and test weight. Singh and Chatterjee (1981) revealed that soaking seeds of three upland rice varieties in water for 24 h, followed by air drying, improved stand establishment by 23 to 43 per cent, compared with non-primed seeds and grain yield by 11–24 per cent over three consecutive years. The results were identical with the findings of Sheela and Alexander (1995) who reported that the grain yield in rice is closely associated and dependent on production of higher number of panicles m^{-2}, number of grains per panicle, panicle weight, thousand grain weight and low sterility percentage. Similar findings on the impact of number of filled grains per panicle on grain yield were reported by Suryaprabha *et al*. (2011) and Rajesh *et al*. (2017). Improved grain yield with seed priming is due to the enhanced dry matter partitioning to the developing grains as a result of greater crop growth rate and LAI. Farooq *et al*. (2005) reported that the higher grain yield in primed seeds might be due to rapid and regulated production of metabolites leading to healthier plants.

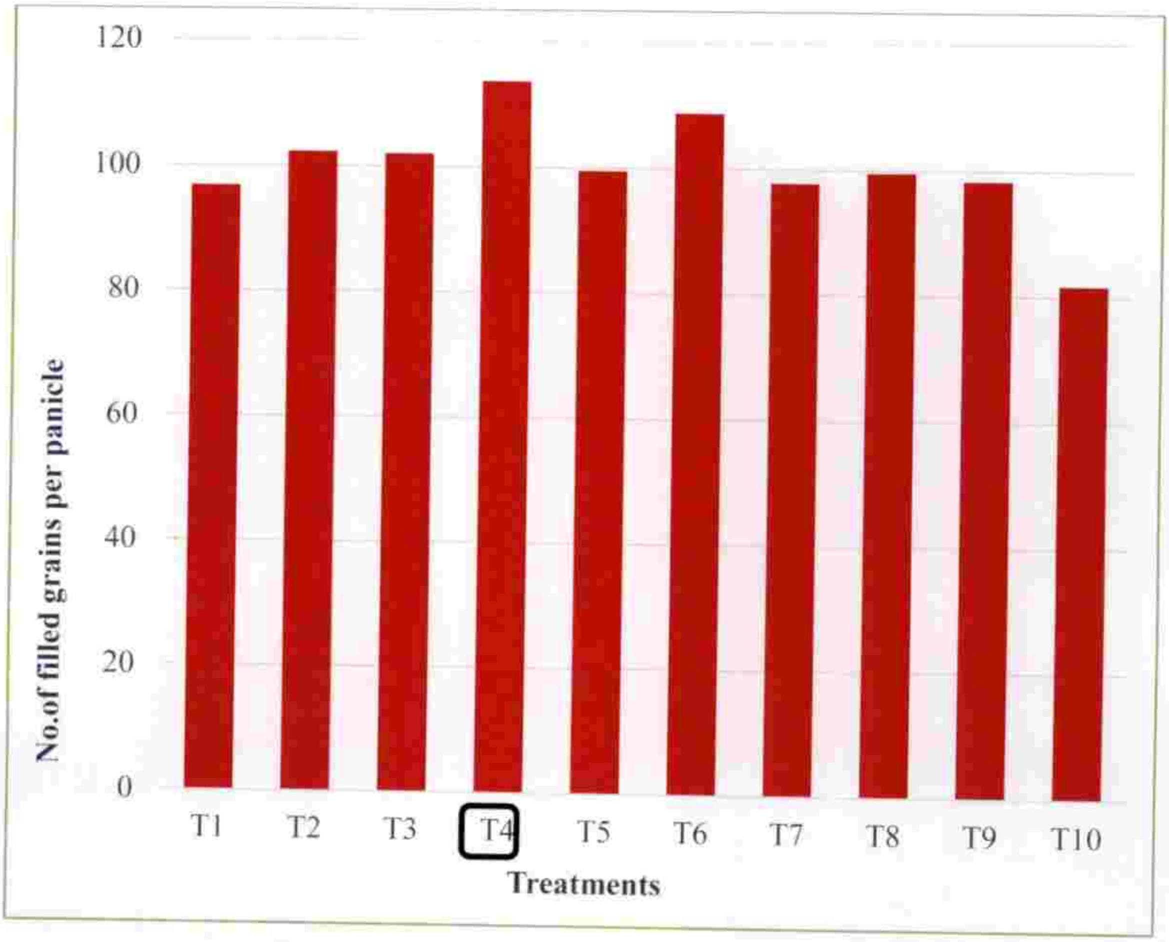

Fig.4.Effect of establishment techniques on no. of filled grains per panicle

The broadcasting treatments at higher seed rates (80 and 100 kg ha^{-1}) recorded higher yields and this might be due to the increased plant population in these treatments which caused a tough competition to the weeds, reducing the uptake of nutrients by weeds and thus making it available to the plants (Fig.5). Singh *et al*. (1995) reported that the grain yield of rice varieties was higher in direct sowing than transplanting (2.01 *vs* 1.99 t ha^{-1}). They also observed that direct seeding in lines produced significantly more panicles m^{-2}, panicle weight and panicle length as compared to transplanting. The seed rate of 100 kg ha^{-1} under broadcasting method was found better in achieving higher yield coupled with more productive tillers m^{-2} and higher test weight (Chauhan *et al*., 2011).

The results were also in agreement with the findings of Singh *et al*. (1997), who reported that the rice cultivar *Aswani* recorded the highest grain yield with the application of 60 kg N ha^{-1} at a seed rate of 80 kg ha^{-1} compared to the other seed rates of 60 and 70 kg ha^{-1}.

Fukai (2002) reported that drill direct seeding with the grain yield of 5.5 t ha^{-1} was significantly superior to transplanted rice (5.1 t ha^{-1}) and marginally superior to broadcasted wet seeded rice (5.2 t ha^{-1}). The higher number of panicles per unit area in drill direct seeding as compared to other methods was reason for obtaining higher yield.

A study conducted in Mossouri, USA by Stevens *et al*. (2012) revealed that dry direct-seeded rice reached 10.3 t ha^{-1} grain yield with 750 mm water input which was far below the water input in transplanted-flooded rice.

Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded a significantly superior straw yield and this might be due to the higher seed rate which resulted in a higher plant population and an increased vegetative growth. The better expression of plant height, tiller m^{-2} and DMP also contributed to an increased straw yield (Fig.6). Establishment methods had no significant effect on harvest index.

5.4 EFFECT OF ESTABLISHMENT TECHNIQUES ON NUTRIENT UPTAKE BY RICE

Nutrient uptake by crop is a function of nutrient content in dry matter and the dry matter production. Nutrient content is related to the photosynthetic activity of leaves because the essential nutrients like N, P and K are both directly and indirectly involved in photosynthesis and respiration. A linear relationship exists between nutrient absorbed by the plant and the grain yield or economic produce (Ramamoorthy *et al.*, 1967).

Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded the highest N uptake, whereas higher P and K uptake were recorded by broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). Since different methods of crop establishment had uniform management practices, a higher uptake in the hydroprimed crop means higher nutrient use efficiency in hydropriming. The higher nutrient uptake in hydropriming might be due to the higher root : shoot ratio observed in these treatments where the enhanced root growth resulted in better uptake of nutrients. Similarly the higher seed rate in treatments T_4 and T_6 resulted in higher plant population resulting in the highest uptake of nutrients.

Hydropriming enhanced the production of vigorous seedlings and also uniform establishment among the plants. This reduced the weed growth and thus the plants obtained more nutrients for absorption from the soil. Nutrient uptake by weeds was directly related to weed DMP and inversely related to rice grain yield

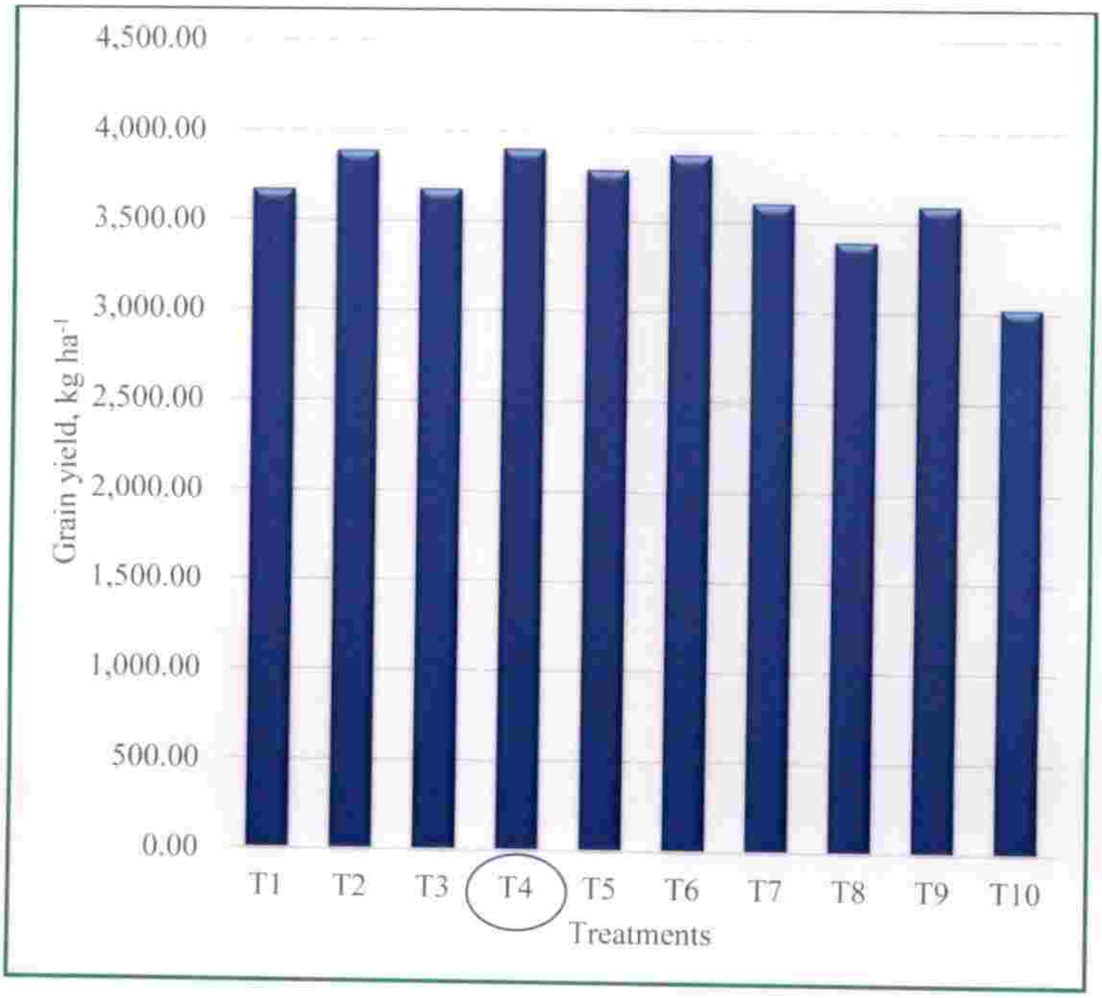

Fig.5.Effect of establishment techniques on grain yield

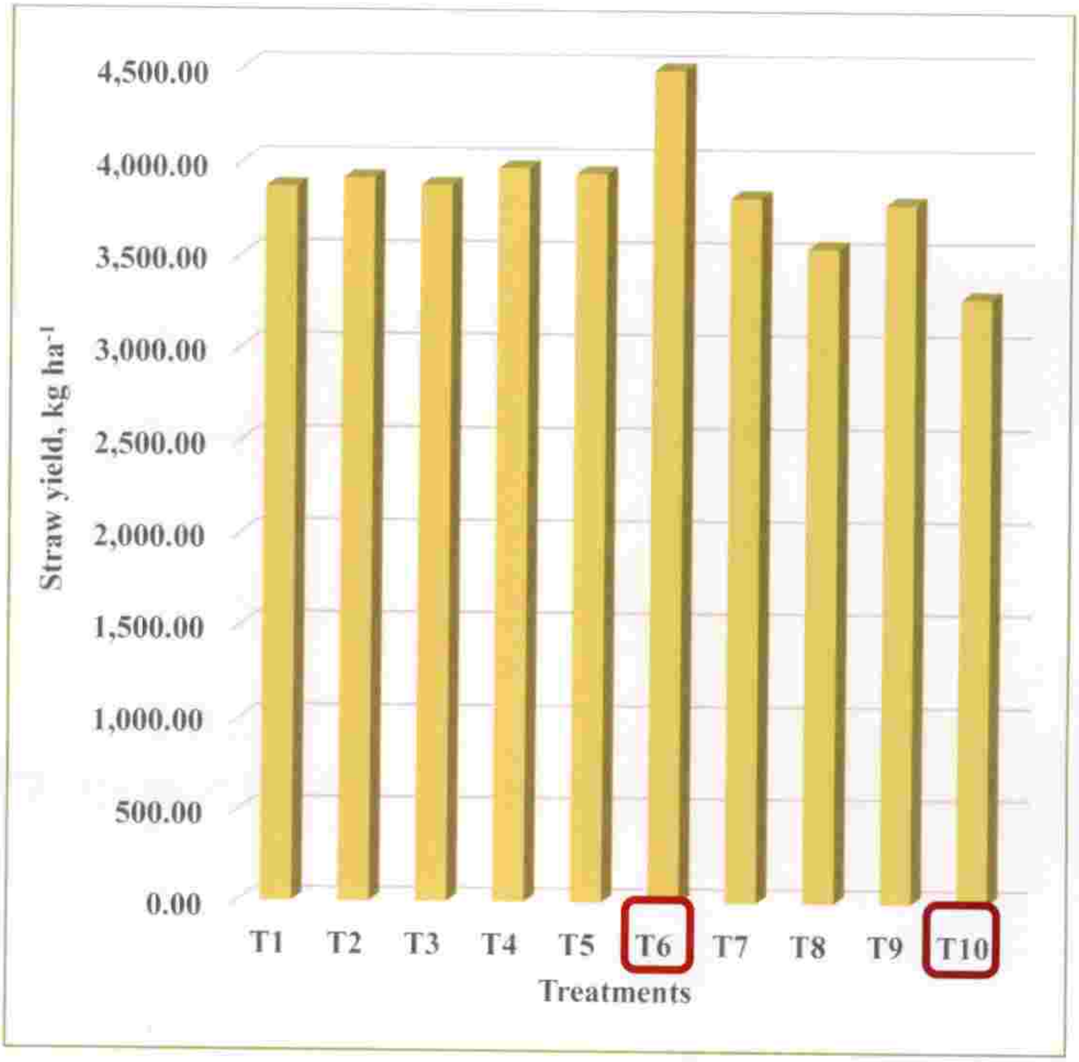

Fig.6.Effect of establishment techniques on straw yield

(Raju and Reddy, 1986). Sharma *et al.* (2007) also reported that initial weed free period resulted in lower weed dry weight and nutrient uptake by weeds and also higher grain yield in direct sown rice.

5.5 EFFECT OF ESTABLISHMENT TECHNIQUES ON SOIL NUTRIENT STATUS AFTER THE EXPERIMENT

Soil analysis data after harvest showed that all the establishment techniques recorded higher organic carbon content compared to initial soil status. This increase is due to the initial application of FYM @ 5 t ha^{-1} uniformly to all treatments. The results of the study by Lynch and Whips (1990) revealed that 40 per cent of the dry matter produced by the plant is released in the form of organic carbon in to the rhizosphere region of the plant. Organic carbon release as root exudates occurs during the crop growth period. Root exudates are organic substrates comprising of simple and complex sugars, amino acids, vitamins, proteins and phenolics which stimulate the growth and proliferation of soil microbes thereby accelerating the decomposition of soil organic matter (Peng *et al.*, 2017). A reduction in the number of tillers was noticed from the previous data on number of tillers m^{-2} at harvest. Suman (2018) reported that the aborted tillers were added to the soil and these tillers decayed also adding organic matter into the soil.

Similar to organic carbon content, the available N, P and K content in the soil were significantly influenced by the establishment techniques. The high soil carbon content among the treatments might be the possible reason for this. Leaching of the nutrients were prevented by the higher organic carbon content in the soil thus improving soil fertility and better availability of nutrients. The study of Sakin (2012) showed that high N content in soil was due to the presence of high soil organic carbon.

5.6 EFFECT OF ESTABLISHMENT TECHNIQUES ON WEED DENSITY AND WEED DRY WEIGHT

The absolute density of weeds including grasses, sedges and broad leaved weeds were significantly influenced by the establishment techniques. Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded the lowest absolute density of grasses and broad leaved weeds. Hydroprimed seeds owing to their faster and uniform emergence intercepted resources and competed effectively with weeds and increased the yield. Line sowing treatments recorded a higher weed absolute density and this might be due to the wider spacing (20 cm) provided in between the rows. Broadcasting seeds at higher seed rate provided benefit in controlling the weed growth as they increased the plant population (Kathiresan and Manoharan, 2002).

The data on weed dry weight (30 and 60 DAS and 25 and 45 DAT) revealed that broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded the lowest dry weight of weeds at 30 and 60 DAS, respectively. The less weed population observed in hydroprimed treatments provided ample space for root growth which may have contributed to the enhanced tiller production in these treatments. It also provided a favourable environment for better availability of moisture, nutrients and sunlight. Seed hydropriming technique enhanced the initial plant growth and the plants with higher tiller number reported a lower weed dry weight. Raj (2016) reported that tillers m^{-2} is an important growth parameter which plays a vital role in weed suppression thus reducing the competition for space, moisture and sunlight finally contributing to high yield.

A higher seed rate, in general, reduced the weed dry weight compared to a lower seed rate because increased seed rate allowed plant population to increase beyond a level that effectively competed with the weeds and kept them controlled. More weed density in lower seed rates might be due to the presence of gaps and greater space that encouraged the weed growth. Walia *et al.* (2009) and Mahajan *et al.* (2011) reported that weed biomass decreased linearly with increased seed rates although increasing seed rate beyond the optimum level had no influence on weed density.

Weeds caused more constraints in DSR than in TPR. Pillai and Rao (1974) reported that extent of yield reduction due to infestation of weeds to be 15 to 20 per cent under transplanted system and 30 to 35 per cent under direct seeded system. The studies of Rao *et al*. (2007) revealed that high weed infestation is a major constraint for broader adoption of DSR

Chauhan *et al*. (2011) observed that rice grown in 30 cm rows had greater weed biomass and less grain yield than in 15 cm. Weed growth and grain yields were similar between 15 cm and 10 cm rows. There was a 94 per cent yield loss in uncontrolled weed growth situations. Similarly in the dry season, plots with no weed control compared to weed free plots indicated a 96 per cent yield loss. In both seasons, crops in wider spacing were vulnerable to weed competition for the longest period. The study also suggested that aerobic rice yields better in 15 cm rows than 30 cm and there is very little benefit of weed control beyond eight weeks after sowing.

Chauhan and Johnson (2010) reported that weed count was observed to be more due to more space available in wider row spacing and also that rice crop sown in wider spacing were vulnerable to weed competition for the longest period (49 days) as compared with narrower spacing (39 days) and had greater weed biomass.

Weed biomass decreased linearly with increasing seeding rates from 15 to 125 kg ha^{-1} (Chauhan *et al*., 2011). Akobundu and Ahissou (1985) pointed out that in the absence of weeds, row spacing (15 to 45 cm) in DSR had little impact on the grain yield of the crop, but in competition with weeds, the widest spacing resulted in significantly lower grain yield.

5.7 EFFECT OF ESTABLISHMENT TECHNIQUES ON ECONOMICS OF UPLAND RICE

Results of the field experiment revealed that the net income and B : C ratio were influenced significantly by the establishment methods. The highest net income and B : C ratio were obtained in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) which was due to its higher grain and straw yield. Broadcasting required lesser labour when compared to line sowing and transplanting methods of planting. Thus a significant reduction in labour charge minimized the cost of cultivation resulting in a higher B : C ratio. Lee *et al.* (2002) also reported that the total cost of rice production by direct seeding was about 21 per cent lower than machine transplanting.

Eventhough line sowing hydroprimed seeds 80 kg ha^{-1} (T_2) recorded a higher grain and straw yield which contributed to its high gross income, the net income and B : C ratio were found to be less than broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4). A total saving of Rs. 4491 ha^{-1} was obtained in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) compared to line sowing hydroprimed seeds 80 kg ha^{-1} (T_2). This reduction was due to the increase in labour required for line sowing of seeds in the field which raised the cost of cultivation.

Thomba method of planting 20 cm x 10 cm (T_{10}) registered the lowest net income and B : C ratio among all the establishment techniques. This was due to the higher labour requirement of transplanting the seedlings in the main field which resulted in a higher cost of cultivation. The total production cost for transplanting was higher than direct seeded rice and the difference was mainly due to the higher labour requirement for transplanting. Pandey *et al.* (2002) reported 50 per cent lower labour use in direct seeded crop than transplanted crops.

The wide spacing adopted in transplanting reduced the plant population and gave a declined grain and straw yield. The declined grain and straw yield also adversely affected the economics of thomba method of transplanting especially in the widely spaced treatment (20 cm x 10 cm).

Jayawardena and Abeysekera (2006) reported that a total saving of around Rs.3500 ha^{-1} due to reduction in labour and seed paddy in broadcast method as compared to transplanting method. Singh *et al*. (2006) reported higher profitability under reduced till direct seeded rice and zero-tillage direct seeded rice by Rs.2745 and Rs.3139 ha^{-1} respectively compared to transplanted rice in Western Uttar Pradesh and Haryana. A study by Erguiza *et al*. (1990) revealed that total cost was 16 per cent higher for transplanted rice, largely because of the high cost of hired labour for crop establishment.

Summary

6. SUMMARY

The study entitled "Standardization of crop establishment technique for upland rice (*Oryza sativa* L.) in coconut garden" was undertaken during 2017-2019 at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala with the objective to find out the most cost effective crop establishment technique for upland rice and to assess its impact on growth and yield of rice.

The experiment was conducted at CRS, Balaramapuram, Thiruvananthapuram during *Kharif* 2018 (May to September 2018). The experiment was laid out in randomized block design with 10 treatments and three replications The treatments comprised of line sowing dry seeds 60 kg ha^{-1} (T_1), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8), thomba method of planting at 15 cm × 10 cm (T_9) and thomba method of planting at 20 cm × 10 cm (T_{10}). Organic manure @ 5 t ha^{-1} and NPK @ 90:30:45 kg ha^{-1} were given uniformly to all treatments. The salient features of the study are summarized below.

The establishment techniques greatly influenced the growth parameters, *viz*., plant height, tillers m^{-2}, LAI, root : shoot ratio and dry matter production.

Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) produced the highest number of hills m^{-2} at 20 DAS which was on par with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and line sowing hydroprimed seeds 60 kg ha^{-1} (T_2).

At 40 DAS, the tallest plants were observed in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) but was comparable with all other establishment techniques apart from thomba method of planting at 20 cm × 10 cm (T_{10}). At 60 DAS also, broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) recorded the tallest plants but was found on par with, all other treatments except broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8), thomba method of planting 15 cm x 10 cm (T_9) and thomba method of planting 20 cm x 10 cm (T_{10}). But at harvest, the tallest plants were observed in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and apart from, line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) and thomba method of planting 20 cm x 10 cm (T_{10}), all other treatments were found statistically comparable with it.

The number of tillers showed an increase at 40 and 60 DAS, whereas a reduction was observed towards harvest. At 40 and 60 DAS, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) produced higher number of tillers m^{-2} compared to other treatments. However, broadcasting hydroprimed seeds at 80 kg ha^{-1} (T_4) recorded significantly higher and superior number of tillers at harvest.

Broadcasting hydroprimed seeds at 100 kg ha^{-1} (T_6) recorded the highest LAI at 40 and 60 DAS, but it was on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), broadcasting dry seeds 100 kg ha^{-1} (T_5) and broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) at 40 DAS and comparable with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and broadcasting dry seeds 100 kg ha^{-1} (T_5) at 60 DAS. Thomba method of planting 20 cm x 10 cm (T_{10}) recorded the lowest LAI both at 40 and 60 DAS.

The root shoot ratio at 50 per cent flowering was the highest in broadcasting dry seeds 80 kg ha^{-1} (T_4), but was on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6). Thomba method of planting 20 cm x 10 cm (T_{10}) recorded the lowest value among all the treatments.

At 40 DAS, broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) had higher DMP and was comparable with all the treatments except, line sowing dry seeds 60 kg ha^{-1}

(T_1), broadcasting dry seeds 100 kg ha^{-1} (T_5), thomba method of planting 15 cm x10 cm (T_9) and thomba method of planting 20 cm x10 cm (T_{10}). The DMP at 60 DAS and harvest was the highest in T_4 and was statistically on par with all the other establishment techniques except, T_1 (line sowing dry seeds 60 kg ha^{-1}),T_3 (broadcasting dry seeds 80 kg ha^{-1}), T_8 (broadcasting pre-germinated seeds 100 kg ha^{-1}) and T_{10} (thomba method of planting 20 cm x 10 cm) at 60 DAS and with T_2 (line sowing hydroprimed seeds 60 kg ha^{-1}) and T_6 (broadcasting hydroprimed seeds 100 kg ha^{-1}) at harvest.

The CGR during 40 to 60 DAS and 60 DAS to harvest were higher in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), which was on par with broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and thomba method of planting 15 cm x10 cm (T_9) during 40 to 60 DAS and with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) during harvest.

Broadcasting hydroprimed seeds at 100 kg ha^{-1} (T_6) recorded higher RGR at 40 to 60 DAS and was on par with T_4. During 60 DAS to harvest, T_4 recorded higher RGR, on par with all treatments except T_3, T_7, T_9 and T_{10}.

Total chlorophyll content at 40 DAS was higher in broadcasting hydroprimed seeds at 100 kg ha^{-1} (T_6), comparable with line sowing dry seeds 60 kg ha^{-1} (T_1), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2) and broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), while broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher chlorophyll content at 60 DAS, on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting hydroprimed seeds at 100 kg ha^{-1} (T_6) and thomba method of planting 15 cm x10 cm (T_9) .

The results of absolute density of grasses at 30 DAS was the lowest in T_6 and was comparable with T_4 and T_8, whereas at 60 DAS it was the lowest in T_4 and was on par with T_6. Absolute density of broad leaved weeds at 30 and 60 DAS were the lowest in T_4 but was comparable with T_6. The absolute density of sedges were less compared to both grasses and broad leaved weeds.

The weed dry weight at 30 DAS recorded minimum in line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), and was comparable with all the other establishment techniques except line sowing dry seeds 60 kg ha^{-1} (T_1), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), thomba method of planting at 15 x10 cm (T_9) and thomba method of planting at 20 cm x 10 cm (T_{10}) and at 60 DAS, the lowest weed dry weight was found with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4).

The period for 50 per cent flowering was the shortest and significant in T_2 (74 days), closely followed by T_4 (78 days), whereas the longest in thomba method of planting at 20 cm x 10 cm (T_{10}) it was the longest (88 days).

Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded higher values for yield attributes. However, it was on par with T_1, T_2, T_5, T_6 and T_9 for number of panicles m^{-2}, with T_6 for number of filled grains per panicle and with T_3 and T_6 for panicle weight. The lowest sterility percentage observed in T_4 was on par with T_2, T_3 and T_6. Establishment techniques had no significant effect on thousand grain weight.

Broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded the highest grain yield (3900.7 kg ha^{-1}) but was comparable with line sowing dry / hydroprimed seeds 60 kg ha^{-1} each (T_1 and T_2); broadcasting dry seeds 80 or 100 kg ha^{-1} each (T_3 and T_5); broadcasting hydroprimed seeds 100 kg ha^{-1}, broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) as well as thomba method of planting at 15 cm × 10 cm (T_9).

Straw yield was the highest and significantly superior in T_6 (broadcasting hydroprimed seeds 100 kg ha^{-1}) and the lowest in thomba method of planting at 20 cm × 10 cm (T_{10}). The establishment techniques had no significant effect on harvest index.

The organic carbon content of the soil was influenced by the establishment techniques. Among the treatments, broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) recorded the highest organic carbon content comparable with T_3, T_5 and T_6.

Establishment techniques had significant influence on the N, P and K uptake by crop at harvest. The highest N uptake was (148.35 kg ha^{-1}) recorded in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6). The highest P and K uptake at harvest was observed in broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and was found to be on par with T_2,T_3,T_5 and T_6 for P uptake and T_3,T_5,T_6 and T_9 for K uptake.

Post-harvest status of available N, P and K levels was significantly influenced by establishment techniques. The available N content after harvest was found higher in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), P in broadcasting dry seeds 100 kg ha^{-1} (T_5) and K in broadcasting dry seeds at 800 kg ha^{-1} (T_3).

Establishment technique had significant influence on the net income of crops. Out of the various establishment techniques practiced, the highest net income was recorded with broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) and was found to be on par with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), T_3 (broadcasting dry seeds 80 kg ha^{-1}), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and broadcasting pre-germinated seeds @ 80 kg ha^{-1} (T_7). Thomba method of planting at 20 cm × 10 cm (T_{10}) recorded the lowest net income.

The B:C ratio was significantly influenced by the establishment techniques. The results indicated that B:C ratio of broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) was the highest and was comparable with line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1} (T_3), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7). Here also, thomba method of planting at 20 cm × 10 cm (T_{10}) recorded the lowest B:C ratio.

From the results, it can be concluded that broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) is the cost effective crop establishment technique for upland rice in coconut garden with a B:C ratio of 1.72. The establishment techniques T_2 (line sowing hydroprimed seeds 60 kg ha^{-1}), T_3 (broadcasting dry seeds 80 kg ha^{-1}), T_5 (broadcasting dry seeds 100 kg ha^{-1}, T_6 (broadcasting hydroprimed seeds 100 kg ha^{-1}) and T_7 (broadcasting pre-germinated seeds 80 kg ha^{-1}) with B:C ratios (1.62, 1.65, 1.66, 1.70 and 1.61 respectively) comparable with T_4 were also found cost effective when compared to other crop establishment techniques.

FUTURE LINE OF WORK

- For confirmatory result, the experiment has to be repeated.
- Spikelet sterility was observed in all the treatments; hence studies have to be undertaken to find out its causes and the best management practices to overcome the same.

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STANDARDIZATION OF CROP ESTABLISHMENT TECHNIQUE FOR UPLAND RICE (*Oryza sativa* L.) IN COCONUT GARDEN

by

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Abstract of Thesis

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ABSTRACT

The study entitled "Standardization of crop establishment technique for upland rice (*Oryza sativa* L.) in coconut garden" was undertaken during 2017-2019 at College of Agriculture, Vellayani, Thiruvananthapuram, Kerala with the objective to find out the most cost effective crop establishment technique for upland rice and to assess its impact on growth and yield of rice.

The research work was carried out at Coconut Research Station, Balaramapuram. The variety used for the trial was Harsha (PTB 55). The crop was raised as an intercrop in 55 year old coconut garden planted at a spacing of 7.6 m x 7.6 m. The field experiment was laid out in randomized block design with 10 treatments and three replications during *Kharif* 2018 (May to September 2018). The treatments comprised of line sowing dry seeds 60 kg ha^{-1} (T_1), line sowing hydroprimed seeds 60 kg ha^{-1} (T_2), broadcasting dry seeds 80 kg ha^{-1}(T_3), broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4), broadcasting dry seeds 100 kg ha^{-1} (T_5), broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6), broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7), broadcasting pre-germinated seeds 100 kg ha^{-1} (T_8), thomba method of planting at 15 cm × 10 cm (T_9) and thomba method of planting at 20 cm × 10 cm (T_{10}). Organic manure 5 t ha^{-1} and NPK 90:30:45 kg ha^{-1} were given uniformly to all treatments.

The results of the study revealed that the establishment techniques had significant influence on most of the growth characters, physiological parameters, weed absolute density, weed dry weight, yield attributing characters and yield of upland rice.

Broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) produced the highest number of hills m^{-2} at 20 days after sowing (DAS) which was on par with broadcasting hydroprimed seeds 80 kgha^{-1} (T_4) and line sowing hydroprimed seeds 60 kgha^{-1} (T_2). At 40 and 60 DAS, T_4 and T_6 produced higher number of tillers m^{-2} compared to other treatments. However, broadcasting hydroprimed seeds at 80 kg ha^{-1} (T_4) recorded

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significantly higher number of tillers at harvest. Broadcasting hydroprimed seeds at 100 kg ha^{-1} recorded the highest leaf area index at 40 and 60 DAS, but it was on par with T_2 ,T_3, T_4 ,T_5 and T_7 at 40 DAS and comparable with T_2, T_4 and T_5 at 60 DAS.

The root shoot ratio at 50 per cent flowering was the highest in T_4, but was on par with T_2 and T_6. The dry matter production at harvest was the highest inT_4, which wason par with T_2 and T_6. Total chlorophyll content at 40 DAS was higher in T_6, comparable with T_1, T_2 and T_4, while T_4 recorded higher chlorophyll content at 60 DAS on par with T_2, T_3, T_6 and T_9.

The CGR during 40 to 60 DAS was higher in T_4, which was on par with T_6 and T_9, but during 60 DAS to harvest higher CGR observed in T_4 was comparable with T_2. Broadcasting hydroprimed seeds at 100 kg ha^{-1} (T_6) recorded higher relative growth rate (RGR) during 40 to 60 DAS and was on par with T_4. At harvest, T_4 recorded higher RGR, on par with all treatments except T_3, T_7, T_9 and T_{10}.

The weed dry weight at 30 DAS was lower in all the treatments except T_1, T_7 and T_{10}, while at 60 DAS, it was found lower in T_4, comparable with T_2, T_6, T_7 and T_9.

The period for 50 per cent flowering was the shortest in T_2 (74 days) and was followed by T_4 (78 days). Broadcasting hydroprimed seeds 80 kgha^{-1}(T_4) recorded higher values for yield attributes. However, it was on par with T_1, T_2, T_5 and T_9 for number of panicles m^{-2}, with T_6 for number of filled grains per panicle and with T_3 and T_6 for panicle weight. The lowest sterility percentage recorded in T_4 was on par with T_2, T_3 and T_6.

Line sowing dry/hydroprimed seeds 60 kg ha^{-1} each (T_1 and T_2); broadcasting dry/hydroprimed seeds 80 or 100 kg ha^{-1}each (T_3, T_5, T_4 and T_6); broadcasting pre-germinated seeds 80 kg ha^{-1} (T_8) as well as thomba method of planting at 15 cm × 10 cm (T_9) were found comparable with respect to their effect on grain yield. Straw yield was the highest in broadcasting hydroprimed seeds 100 kg ha^{-1} (T_6) and the lowest in thomba method of planting at 20 cm × 10 cm (T_{10}). Line sowing hydroprimed seeds 60 kg ha^{-1} (T_2); broadcasting dry/hydroprimed seeds 80 or 100 kg ha^{-1} each (T_3, T_5, T_4 and T_6) and broadcasting pre-germinated seeds 80 kg ha^{-1} (T_7) were found to be economical compared to other treatments.

From the results, it can be concluded that broadcasting hydroprimed seeds 80 kg ha^{-1} (T_4) with a grain yield of 3900.7 kg ha^{-1} and B: C ratio of 1.72 is the cost effective crop establishment technique for upland rice in coconut garden.

സംഗ്രഹം

"തെങ്ങിൻ തോപ്പിലെ കരനെല്ല് കൃഷി സാങ്കേതികതയുടെ മാനദണ്ഡീകരണം" എന്ന വിഷയത്തെ ആസ്പദമാക്കിയ ഗവേഷണ പഠനം 2017-19 കാലയളവിൽ വെള്ളായണി കാർഷിക കോളേജിൽ നടത്തുകയുണ്ടായി. ഇതിനായുള്ള വിളഭൂമി പരീക്ഷണം ബാലരാമപുരത്തുള്ള തെങ്ങ് ഗവേഷണ കേന്ദ്രത്തിൽ 2018 മെയ് മുതൽ സെപ്റ്റംബർ വരെയാണ് നടന്നത്. ഏറ്റവും ചെലവ് കുറഞ്ഞ വിള സ്ഥാപനരീതി മനസിലാക്കുക അതോടൊപ്പം നെല്ലിൻറെ വളർച്ചയിലും വിളവിലും അതിൻറെ സ്വാധീനം വിലയിരുത്തുക എന്നിവയായിരുന്നു പഠനത്തിൻറെ പ്രധാന ലക്ഷ്യങ്ങൾ.

ഹർഷ എന്ന നെല്ലിനമാണ് പഠനത്തിനായി ഉപയോഗിച്ചത്. പത്തു രീതികളിലാണ് ഗവേഷണം നടത്തിയത്. ഹെക്ടറൊന്നിന് 60 കി.ഗ്രാം എന്ന വിത്തുനിരക്കിൽ, ഉണങ്ങിയ വിത്തുകളുടെയും ഹൈഡ്രോ പ്രൈംഡ് വിത്തുകളുടെയും വരി വിതയ്ക്കൽ, ഹെക്ടറൊന്നിന് 80 കി.ഗ്രാം വിത്തുനിരക്കിലും 100 കി.ഗ്രാം വിത്തുനിരക്കിലും ഉണങ്ങിയ വിത്തുകളുടെയും ഹൈഡ്രോ പ്രൈംഡ് വിത്തുകളുടെയും വിതയ്ക്കൽ, ഹെക്ടറൊന്നിന് 80 കി.ഗ്രാം വിത്തുനിരക്കിലും 100 കി.ഗ്രാം വിത്തുനിരക്കിലും മുളപ്പിച്ച വിത്തുകളുടെ വിതയ്ക്കൽ, രണ്ടു വ്യത്യസ്ത അകലങ്ങളിൽ തോമ്പാ നടീൽ രീതി എന്നിവയാണ് രീതികൾ .

80 കി. ഗ്രാം വിത്തുനിരക്കിൽ ഹൈഡ്രോ പ്രൈംഡ് വിത്തുകളുടെ വിതയ്ക്കൽ ആണ് കൂടുതൽ ധാന്യ വിളവും ചെലവ് കുറഞ്ഞ വിള സ്ഥാപനരീതിയുമെന്ന് ഗവേഷണത്തിലൂടെ കണ്ടെത്തി. ഹെക്ടറൊന്നിന് 100 കി.ഗ്രാം വിത്തുനിരക്കിൽ ഹൈഡ്രോ പ്രൈംഡ് വിത്തുകളുടെ വിതയ്ക്കൽ ആണ് ഏറ്റവും കൂടുതൽ വൈക്കോൽ വിളവ് നൽകിയത്.

Appendix

APPENDIX 1

Weather data during the crop season (May 2018- September 2018)

Standard week	Temperature, ^{0} C		RH, %		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
22	31.08	21.07	93.17	79.1	69
23	31.2	20.84	96.43	85.7	127.6
24	31.18	19.65	90	80.5	64.5
25	31.74	19.91	92	83.1	57.1
26	31.47	20.18	89.4	80.4	26.8
27	30.64	18.67	90	75.2	13.4
28	29.24	19.71	86.1	85.2	70.2
29	30.2	19.27	91.2	79.2	56.8
30	31.42	19.24	88.5	74.5	12.9
31	29.4	19.52	90.4	80.9	137.8
32	30.38	19.58	91	85	107.1
33	29.61	18.84	93.3	89	206.8
34	31.08	21.02	89	77	2.9
35	31.12	19.87	89.1	71	0
36	32.62	20.71	87.1	72.9	0
37	33.71	19.47	84.2	70.7	0