Contents

[**Chapter 01** 2](#_Toc529958327)

[**Introduction** 2](#_Toc529958328)

[**1.1 Objectives** 4](#_Toc529958329)

[**1.1.1 General** 4](#_Toc529958330)

[**1.1.2 Specific** 4](#_Toc529958331)

[**Chapter 02** 5](#_Toc529958332)

[**Literature Review** 5](#_Toc529958333)

[**2.1 Rice plant** 5](#_Toc529958334)

[**2.2** **Rice cultivation in Sri Lanka** 5](#_Toc529958335)

[**2.4 Constrains with Rice Cultivation in Sri Lanka** 6](#_Toc529958336)

[**2.4 Direct seeding of Rice** 6](#_Toc529958337)

[**2.5 Transplanting of Rice** 6](#_Toc529958338)

[**2.51Wet bed for Random transplanting** 6](#_Toc529958339)

[**2.52 Parachute method** 6](#_Toc529958340)

[**2.53 Mechanical transplanting** 6](#_Toc529958341)

[**2.531 Transplanters** 6](#_Toc529958342)

[**2.532 Problems with Mechanical Transplanting in Sri Lanka** 6](#_Toc529958343)

[**2.7 Seedling Vigor** 6](#_Toc529958344)

[**2.8 Growth parameters of seedlings** 6](#_Toc529958345)

[**2.9 Early Growth parameters of rice plants** 6](#_Toc529958346)

# **Chapter 01**

# **Introduction**

The Asian rice (*Oryza sativa*) can be classified as the foremost cereal crop in Sri Lanka. The rice cultivation is distributed in most parts of Asian countries which is more than ninety per cent of the lands total cultivated lands extent as the staple food. Rice act as the principal contributor of Sri Lankan rural economy. Sri Lanka is a developing country with estimated total land devoted for cultivation is about 792,000 ha (CBSL, 2017). The national average rice yield of Sri Lanka in kilogram per net hectare is 4,349 in Maha and 3092 in Yala season (Department of census and statistics, 2016). And also the annual per capita consumption of the rice is 105kg (Sri Lanka World Bank Group, 2008). According to the annual report of the Central Bank of Sri Lanka in 2017 about 748,000mt rice imported to our country. The demand for the rice is increasing rapidly due to the increment in the population and the per capita rice consumption. The production and the productivity of the rice should be increased rather than increasing the cultivated land extent through better field practices to meet the increasing demand of rice(Dushani and Sandika, 2009)

The cultivation of rice is practised in all the parts of the country as a wetland crop except at the high altitudes, which act as the principal contributor on the rural economy (Henegedara, G.M., 2002). Mainly two cultivation seasons known as Maha and Yala which are equivalent with two monsoons are practised in Sri Lanka. In generally transplanting and the direct seeding of rice are the two main methods of rice cultivation practised in Sri Lanka considering the variations in different ecological regions at where rice is cultivated. The sowing of seeds directly in the field is practised in direct seeding method and the seedlings are raised in seedbeds and then planted in the field in the transplanting method.

In Sri Lanka DSR is practiced by more than 95% of total land extent devoted for rice cultivation as it is considered as an alternative option to lack of sufficient labour force and high cost for labors at the peak transplanting period which cause delayed transplanting and reduced yield in transplanting method (Weerakoon et al., 2011; Santhi et' al., 1998). The problems associated with DSR are, no proper spacing, management practices are difficult and most disastrous problem is the invasion of weeds and weedy rice (Gunawardana et al., 2013; Marambe, 2009). As a solution for this farmer tends to use agrochemicals to control weeds which is not an environmentally friendly practice.

Transplanting is commonly practised in most parts of the Asian countries (Mabbayad and Bordo, 1971). Transplanting of the seedlings on the puddled soil can be done manually as rows or randomly and through machine transplanting. Transplanting of rice gives a significantly higher yield than the direct seeding as it produces more number of productive tillers which bares panicles with an increased number of spikelet’s than the direct seeded rice plants (Fan et al., 2003). Although the labour intensity and labour costs are high in transplanting compared to the direct seeding of rice, highest yield and income is reported from it(Manjappa and Kataraki, 2004; Rani and Jayakiran, 2010).

As the most feasible solutions to increase the yield from rice cultivation proper nursery management practices which gives vigorous seedlings and transplanting of them at the correct time can be used. Mainly in Sri Lanka transplanting is done using dapog nurseries, parachute nurseries, wet bed and dry bed nurseries.

Mechanical transplanting of rice is the best solution for the problems with transplanting method including high labor intensity and delayed transplanting of seedlings. Mechanical Transplanting is the method of transplanting the seedlings which are raised on trays or mats uniformly with optimum plant density and less transplanting shock compared to other transplanting methods, using self-propelled mechanical transplanter. The self-propelled walk behind type transplanter is considered as a popular transplanter among the farmers in Asian countries which gives significantly increased the rice yield. A plastic tray is introduced to as nursery trays in modified dapog nurseries which is compatible with the dimensions of the feeding platform in the transplanter, to increase the convenience of handling seedlings, rather than using mat type nurseries which needed to be cut into parts according to the size of the feeding platform. Although the Ministry of Agriculture and the Department of Agriculture implemented programmes to promote the Mechanical Transplanting in Sri Lanka, very low adaptability of farmers to this method due to the constraints with nursery establishment, lack of technical knowledge and socio-economic reasons. So, it is a timely requirement to do studies on efficient utilization of the mechanical transplanter and introduced them to the farmers to increase the rice production. As introduced recently there is no recommended seeding rate to be used in the nursery trays used for Mechanical transplanting, it is understudied. Generally, use seeding rate between 60g - 150g per tray (Alizadeh et al., 2011; Columbia and Division, 2013; Islam and Khan, 2017).

Seeding rate can be defined as the amount of the seeds from an individual plant species required to achieve optimum seedling density in the nursery with an increment in the vigor of seedlings (Louisiana, 2009). The seedling vigor is the ability of the plant to emerge from the substrate rapidly and cover the ground surface rapidly (Deseo, 2012). Planting of vigorous seedlings is important factor on the early plant growth of the plants after the establishment which increases the number of productive tillers and the rice yield per unit area by decreasing the mortality rate of seedlings due to the transplanting stress (Panda et al., 1991; Tekrony and Egli, 1991).

Following proper nursery management practices is very important factor which affects on the seedling vigor and early plant growth of rice after field establishment in all the transplanting methods. Studies on the optimum seed rate for the nursery trays of Mechanicaly transplanted rice on seedling vigor and the early plant growth of rice have not been yet investigated properly in Sri Lanka. The main intention of this study is to identify the optimum seeding rate for the nursery trays use for mechanical transplanting and compare the seedling vigor and early plant growth with direct seedling, wet bed nurseries used for random transplanting and with parachute method of transplanting.

## **1.1 Objectives**

### **1.1.1 General**

To identify the optimum seeding rate in nursery trays for Machine transplanting and comparison of seedling vigor and early plant growth with other nursery methods

### **1.1.2 Specific**

To find out the effect of seeding rate on different growth parameters of the seedlings in modified dapog nursery trays.

To identify the effect of different nursery methods on the vigor of the seedlings and early plant growth.

# **Chapter 02**

# **Literature Review**

**Paddy Cultivation in Sri Lanka**

Rice is the main cereal crop cultivated in Sri Lanka which act as the main contributor of the rural economy by occupying more than 26.1 percent of the labor force (CBSL, 2018). Sri Lanka is consisting with different ecological regions which contains wide range of climatic conditions most suitable for rice. The cultivation of rice is practiced in all the parts of the country except at higher elevations (Dhanapala, 2000; Henegedara GM, 2002). The land area under rice cultivation acquires about 34 percent of the total land area devoted for cultivation in Sri Lanka which is about 792,000 hectare in 2017, including 543,00 hectare in Maha season and 249,000 hectares in Yala season (CBSL, 2017; “The importance of rice in Sri Lanka | Blue Lanka,” 2018).

According to the Sri Lanka World Bank Group, 2008, the average per capita consumption of rice by the Sri Lankans is 105kg per year. The average yield obtained from the rice cultivation per hectare is 4297 kg which is not sufficient to fulfill the total requirement of the country. The annual rice production in the year 2017 is estimated as 1.7 million metric tons which is sufficient for only 8 months period to fulfill the total requirement in the country. So, on behalf of the food security in the country the deficit amount, 800,000 metric tons is imported (CBSL, 2017).

Rice is the staple food of 20.8 million Sri Lankans which has 0.5 percent contribution on the GDP which is 72,809 million rupees in value (CBSL, 2018). More than 1.8 million farmers in all around the country depends on the rice cultivation from which they earn their livelihood (“The importance of rice in Sri Lanka | Blue Lanka,” 2018). According to the Department of Agriculture rice consumption accounts for 45% of the total calorie requirement and 40% of the total protein requirement of an average Sri Lankan.(Rice Research & Development Institute Bathalagoda, 2017)

**Constrains to the Rice Cultivation in Sri Lanka**

Most of the developing countries situated in the Asia-Pacific Region including Sri Lanka are extremely affected by the yield gap between the potential yield and the actual yield received due to many circumstances (Food and Agriculture Organization of the United Nations, 2000). The demand on the rice is increasing with increase of the population as 1.2% annually (Thiruchelvam, 2005). The total land extent utilized by the paddy cultivation is decreasing rapidly. According to the CBSL, 2017, the land extent cultivated in 2017 is 791,679 hectares which is a 28.9% reduction compared to past few years. The average yield gained per hectare from the past decades including 2015,2016,2017 is respectively 4429kg, 4372kg, 4292kg. It proves that there is no increment in the yield obtained although the population and the demand for the rice increased annually(CBSL, 2017)

The aim of the Asian countries including Sri Lanka to reduce the rice yield gap through increasing the production to confirm the food security and economic stability in the country (FAO Sri Lanka, 2012; Food and Agriculture Organization of the United Nations, 2000). The out put from the rice cultivation can be increased and generate a surplus for the exportation through expanding of the area cultivated, improving the yield or using the both options. The problem with Sri Lanka is that there is no any additional land that can be occupied to improve the production. So the most logical solution to tackle with this problem is to increase the productivity of rice (“Sri Lanka as a Rice Exporting Country: Possibilities and Problems,” 2011). The highest yield potential areas can achieve a high yield which is about 6 metric tons per hectare whereas the average annual yield in Sri Lanka for past few years is around 4.5 metric tons per hectare. So, to achieve the self sufficiency and generate surplus to export, a quantum jump is required in the Rice cultivation sector in the Sri Lanka, otherwise there is no any solution to cope with the increasing demand rather increasing the amount of rice importation proportionally (“Sri Lanka as a Rice Exporting Country: Possibilities and Problems,” 2011).

The major constrains associated with the farmers’ in rice cultivation except the rice yield gap are, invasive weeds, weedy rice, high occurrence of damages from pests and diseases, increased cost on the inputs including labor and the chemicals applied (Akbar et al., 2007; Perera et al., 1990). The aggressive weeds and weedy rice considered as a very common problem found in Sri Lanka. It is serious constraint that reduced the final yield and the occurrence is highly observed in the Direct seeded fields.(Caton et al., 1999; Ratnasekera, 2015; Zhao et al., 2006).

The prevalence of the pest and diseases which adversely make an impact on the yield, also among the major problems associated with Rice cultivation. The root cause for the invasion of pests and diseases is the improper field establishment of plants without maintaining the optimum spacing between the plants. The susceptibility of the plants in the direct seeded field for pest and diseased also high compared to the other methods of establishment (Iqbal et al., 2017). It is a more critical problem in Sri Lanka as more than 90 percent of the farmers choose the direct seeding as a solution to the labor shortage and high cost of production in transplanting method, although the yield gained from the transplanting is high compared to the direct seeding (MoADR, 1989; Weerakoon et al., 2011).

So as the most suitable solution farmers select the application of chemicals to control the pests, diseases, weeds and weedy rice. As it is available at cost effective prices, they tend to use in excessive amounts than the recommendations with the aim of annihilating them from the field. This is the root cause for health risks including kidney diseases which is a most popular sympathetic problem among the rural farmers (“Agrochemical pesticides and kidney related diseases, Sri Lanka | EJAtlas,” 2016; Rajapakse et al., 2016).

Another problem associated with the rice cultivation is high cost of production. The most expenditure of Manual transplanting is occupied by the labor charges which accounts for about 40% - 50% of the total expenditure (Clayton, 2010; Vidanapathirana, 2003). And also, improper nursery management practices, delayed transplanting of seedlings, careless transplanting by the labors with increased missing hill percentage and reduced plant density are commonly observed consequences between the Sri Lankan farmers which reduced the rice yield obtained (Columbia and Division, 2013; Das, 2012; Farooq et al., 2001; Illangakoon et al., 2017).

The most feasible solution to reduced the problems associated with rice cultivation in Sri Lanka is to find out the possible substitutes to avoid these constraints with the help of new technological changes. For that the research efforts are very important because the evaluation of each modern technology considering their suitability for Sri Lankan conditions and make adjustments accordingly before introducing to the farmers is very essential. The problem is only a marginal proportion of the GDP is allocated for Agricultural Research and Extension in Sri Lanka during the past decades (“Sri Lanka as a Rice Exporting Country: Possibilities and Problems,” 2011).

## **2.4 Direct seeding of Rice**

In the Direct Seeding method of crop establishment, the rice seeds are sown directly in the field. Direct seeding of rice is practiced in both wet and dry soil as wet direct seeding and dry direct seeding and water seeding through broadcasting, dibbling, drilling or sowing of seeds in lines (IRRI Rice Knowledge Bank, 2018). Wet direct seeding is the method of sowing pre-germinated rice seeds in to the puddled soil whereas sowing of dry seeds is practiced in Dry direct seeding of rice. The seeds are sown in the standing water conditions at the Water seeding method which is sub divided in to aerobic and anerobic according to the oxygen content available in the ambient water of the germinating seeds (Hassan Akhgari, 2011). The main purpose of the Water seeding is to control the invasive weeds and weedy rice which are the major constraints in Direct seeding (Hill et al., 1990). Dry direct seeding is practiced in the areas which are prone to floods and in low lands, uplands where rainfed paddy cultivation is done. The lands where irrigated cultivation of rice is done commonly used the Wet direct seeding method (Pandey et al., 2000).

The cultivation of rice through direct seeding is widely practiced in America, Russia, Japan, Cuba, India, Western Europe including Italy, French as a result of the shortage of skilled labor and high wages demanded by them (Iqbal et al., 2017). According to the Weerakoon et al., 2011 direct seeding is practiced in about 95% of the total cultivated area of rice in Sri Lanka and the wet direct seeding is the most commonly practiced method of direct seeding primarily as a solution to the labor intensity. The Direct seeding of rice became the most common method practiced by the farmers in spite of the efforts of the Department of Agriculture to popularize the transplanting method as the most favorable planting technique for rainfed and irrigated environments (Pathinayake et al., 1990).

Although in the Asian region farmers mainly followed the traditional transplanting method of rice, at present the farmers tend to adopt to the direct seeding as the most suitable option to the increasing labor shortage during the peak transplantation period and high costs on wages. The land area at which the direct seeding method of rice is followed in Asia, is rapidly increasing because the ultimate goal of the farmers in this area who earn their lives through rice cultivation is to increase the productivity and profitability to gain high net retain as the income (Pandey et al., 2000).

Mainly the farmers tend to use direct seeding when there is lack of available resources like land, labor and if there is a necessity for the early maturity of the plants (IRRI Rice Knowledge Bank, 2018). The improved short duration rice varieties and the availability of selective herbicides at cost effective prices impelled the farmers more on the Direct seeding (Pandey et al., 2000). The direct seeding of rice helps to reduce the water usage for about 30% compared to the conventional transplanting method which requires water for raising seedlings, puddling the soil and also for maintaining the water level at the height of 4 to 5 inches after transplanted in the field (Sangeetha and Baskar, 2015).

The invasion of the weeds and weedy rice is concerned as the most distractive problem in direct seeding of rice (Gunawardana et al., 2013; Marambe, 2009). The damages from the diseases and the insect pest attacks, severe in the direct seeding compared to the transplanting as the increased plant density creates a shadier, humid, cooler environment inside the plant canopy which is favorable for the multiplication of them (Pandey et al., 2000). As the chemicals are available at cost effective prices the farmers tend to use excessive amount of them to control the weeds, weedy rice, pest and diseases which cause the contamination of ground water that laid the foundation for the kidney diseases and also weed varieties with resistant genes for the herbicides are formed due to frequent application of chemicals (Illangakoon et al., 2017; Rajapakse et al., 2016). The available nutrients and the moisture content for the direct seeded plants is at low level compared to transplanting, due to the increased weed density and the shallow nature of the roots which caused it unable to absorb sufficient amount of nutrients to the plants through deep penetration (Singh et al., 1981). As a result of these reasons there is a significant reduction in the grain yield obtained from direct seeding compared to the transplanting of rice (Akbar et al., 2007)

## **2.5 Transplanting of Rice**

The transplanting of rice is the most commonly practiced traditional establishment method by the farmers in the Asian region (Mabbayad and Bordo, 1971). The pre-germinated seeds are sowed at the nursery beds at where the seedlings are raised until they reached the correct age for transplanting. The type of nursery bed use for raising seedlings is decided according to the availability of water, labor, land and the mechanization methods followed. The nursery types which are used for transplanting are Wet bed, Dry bed, Dapog, Modified dapog nurseries in mats and trays, Parachute nurseries in the trays (bubble trays). The transplanting of rice is the process of uprooting the seedlings form the when at the correct seedling age for the field establishment and replanting of them in the fields in which puddling and leveling is done. The transplanting of rice can be done either manually or mechanically. The manual transplanting of rice is the most popular transplanting method among the Asian farmers (IRRI, 2007).

The most important factors to concern in the transplanting of rice in order to achieve a vigorous stand of plants in the field after established in the field are, properly managed nutrient application to the plants, optimum seed rate for seed beds and transplanting of tender seedlings at the correct age by avoiding the delayed transplanting of seedlings (Himeda, 1994; Lal and Roy, 1996). The advantages of the transplanting of rice compared to other establishment methods are, optimum spacing between the plants in facilitating the agronomic practices like weeding, low seed rate required for the nurseries, ability of the plants to withstand over the weeds and the uniform maturity of the crop can be obtained (Desai, 2012). As the transplanted rice plants has the ability to compete and suppress the weed growth, higher economic yield can be obtained from the transplanted rice through proper weed management measures (Hossain et al., 2002). And also due to the optimum space between rice plants maintained by the transplanting method, a significant increase in the yield can be observed as the low plant density and proper penetration of sunlight through the canopy of the plants reduced the occurrence of pest and disease damages compared to direct seeding of rice (Baloch et al., 2002).

The transplanted rice cultivation gives significantly increased number of productive tillers per hill and increment in number of spikelets per panicle which ultimately gives an increased gran yield compared to the direct seeding. The deep penetrated and the wide spread root system of the rice plants facilitate the plants with sufficient amount of nutrients and moisture content during the panicle initiation and flowering stages which are considered as more critical stages having a noticeable impact on the final yield (Septiningsih et al., 2003).

The main problems associated with the transplanting are, the deficit and overhead costs on the labors at the peak transplanting period which is the root cause for the delayed transplanting of seedlings. It is a time consuming establishment method and requires more expenditure on the nursery management, uprooting of seedlings and transplanting of them to the field (Das, 2012; Singh et al., 2018).

The highest gross economic return can be obtained from the transplanting of rice than other establishment methods with the availability of ample amount of labors for field practices. The throwing of seedlings which is known as the parachute method can be used as an appropriate solution to tackle the problem scarcity of labors and improve the harvest (Akbar et al., 2007; Manjappa and Kataraki, 2004; Rani and Jayakiran, 2010). The mechanical transplanters can be named as the most attractive suggestion to the areas with shortage of labor (Singh et al., 2018).

**2.6 Seeding rate**

Seeding rate can be defined as the amount of seeds required toacieve the adequate seedling density in the nursery bed or the field (Louisiana, 2009). Better seeding density is an important factor to consider among the components of nursery management practices for vigorous plant growth (Lal and Roy, 1996).

The seeding rate applied for the nursery trays depends on the variety and the germination percentage. The seedling density is decided according to the seeding rate applied and it eventually decided the requirement of nursery trays for the field establishment(Islam et al., 2015; Islam and Khan, 2017)**.** So, it is important to have an optimum seeding rate to use in the nursery trays used for the machine transplanting to optimize the yield in a cost-effective manner. The seeding rate which is applied for the nursey trays ranged from 60g – 150g seeds per tray (Alizadeh et al., 2011; Columbia and Division, 2013; Islam et al., 2016, 2015; Islam and Khan, 2017)

The seeding rate is having an influence naturally on the growth and the density of seedlings in the nursery. The thin sowing seeds give strong, vigorous, tillered seedlings that can withstand over the adverse climatic conditions with better stand of plants after field establishment whereas the thick sowing produced thin, tall, weak seedlings without tillers that susceptible highly for the transplanting shock which retarded the growth of plants after field establishment (Hossain et al., 2002; Oparka and Gates, 1982; Sarwar et al., 2014).

The farmers tend to use high seed rate in the nursery on behalf of avoiding the weed competition and make it easy for uprooting the seedlings for transplanting. The uprooting of seedlings and separation of them for transplanting, is the most critical process at which the root damages occurred. The proportion of roots damaged is increasing with the seed rate which is considered as the major reason for the transplanting shock that adversely effect on the early plant growth of the plants after established in the field. As the early plant growth is one of the main contributors on the final grain yield the optimum seed rate for the nursery trays is an important factor to consider at nursery establishment (Lal and Roy, 1996; Panda et al., 1991; Sarwar et al., 2014; Singh et al., 2005). According to the Islam et al., 2015 the number of seedlings which are dispensed per stroke, the amount of missing hills and the uniformity in the establishment of seedlings in the machine transplanting depends on the seeding rate used in nursery trays.

### **2.53 Mechanical transplanting**

The mechanical transplanting is the field establishment of the seedings raised in a modified dapog nursery as mat type or nursery trays, using the rice transplanters (Rickman et al., 2015). Mechanical transplanting is reorganized as the most provable solution to tackle with the problems related with the conventional methods of transplanting, in order to increase the productivity and the profitability obtained by the farmers (Illangakoon et al., 2017). The final yield is significantly increased by the mechanical transplanting method of plant establishment compared to other methods, through optimum plant density with adjustable spacing between the plants, less amount of missing hills and reduced transplanting shock with the seedling friendly transplanting method followed in the self-propelled walk behind type transplanter which is commonly used in Asian countries (Gaikwad et al., 2015; Islam et al., 2016; Rickman et al., 2015).

The popularization of the Mechanical transplanting between the farmers in the Asian region at where the farmers are highly adopted to the manual transplanting of rice has become a very important factor (Farooq et al., 2001). The Department of Agriculture, Sri Lanka has launched programs to give the technical knowledge to the farmers under the projects KOPIA and Yaya II, to develop an instinct on them to adopt to this new technology. (Bandara et al., 2017; Sri Lanka raises rice productivity with Korean technology, 2016)

The mechanical transplanting of rice increases the labor use efficiency which assures timeliness transplanting with speed transplanting while generating an alternative income source for the rural youth as operators in machines and in different nursery management practices. (Islam et al., 2016; Islam and Khan, 2017) For the manual transplanting of rice requires 8-12 labors for one hectare whereas only 3 labors are required to transplant 4 hectares with in one day. Mechanical transplanting can be considered as an operation with low health risk on labors when compared with the fatigue manual transplanting of rice with frequend bending and straighten up process which is not an ergonomically friendly. (Pradhan and Mohanty, 2014; Rickman et al., 2015)

The area required for the nurseries used for the mechanical transplanting is smaller than the space requirement for the conventional nurseries and it requires soil alone without pebbles to use as the media for raising seedlings. The amount of seed paddy requirement also low when compared with the direct seeding method of plant establishment.(Columbia and Division, 2013; Gaikwad et al., 2015; Hayleys empowers greater productivity via mechanised rice transplanter, 2013) The production cost can be reduced from 25% - 30%through the mechanical transplanting than the manual transplanting (Mahbubur Rashid et al., 2015).

The optimum space between the plants in this method ensures the photosynthesis efficiency and the vigorous growth of the plants through better penetration of sunlight, increased air circulation with the wide spread and deep percolated root system that facilitates efficient utilization of moisture and nutrients. The low plant population in the manual transplanted field ,which is a critical factor that affect the final grain yield can be avoided through mechanical transplanting. (Baloch et al., 2002; Farooq et al., 2001) The seedlings are pegged firmly in to the soil which reduced the transplanting shock and a uniform crop stand with vigorous growth can be obtained after field established using the transplanter (Illangakoon et al., 2017; Rickman et al., 2015).

Rice plant

The Rice (*Oryza sativa* L.) is among the world wide cultivated cereal crops in the world which is next to the wheat

Oryza sativa was first cultivated in south-east Asia, India and China between 8 000 and 15 000 years ago (OECD 1999; Normile 2004).

Rice is also grown from sea level to 3 000 m and in both temperate and tropical climates. A variety of water regimes are used, including unsubmerged upland rice (10% of total cultivation), moderately submerged lowland rice (irrigated, 45%, or rain-fed, 30%), and submerged rice (up to six m of water, 11%, or floating, 4%). Rice can grow in a wide range of soil types as well, including saline, alkaline and acid-sulfur soils (Takahashi 1984b; Oka 1988; Ahn et al. 1992; OECD 1999

The genus Oryza belongs to the tribe Oryzeae of the family Poaceae (http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi). There are 12 genera within the Oryzeae tribe (Vaughan 1994). The genus Oryza contains approximately 22 species of which 20 are wild species and two, O. sativa and O. glaberrima, are cultivated (Vaughan 1994).

O. sativa is the most widely grown of the two cultivated species. It is grown worldwide, including in Asian, North and South American, European Union, Middle Eastern and African countries. O. glaberrima however, is grown solely in West African countries. O. sativa and glaberrima-sativa hybrids are replacing O. glaberrima in many parts of Africa due to higher yields (Linares 2002)

The Biology and Ecology of Rice ( Oryza sativa L .) in Australia

Rice (Oryza sativa L.) is grown successfully in regions having the necessary warmth and abundant moisture favourable to its growth, be it under lowland or upland condition. It is one of the most important and indispensable caloric cereal food crop in Ghana. Beyond providing sustenance through growing, earning income and consuming, rice plays an integral, but important cultural role in many rural communities of Ghana

“ DIGANG ” RICE ( Oryza sativa L .) UNDER UPLAND CONDITION OF BAWKU , UPPER EAST REGION , GHANA

## **2****.4 Constrains with Rice Cultivation in Sri Lanka**

low yield of transplanted rice, poor nursery management seems to be a major cause due to which seedlings cannot perform well after transplanting in the main fiel

Influence of Nursery Management and Seedling Age on Growth and Economic Performance of Fine Rice

rice cultivation is a labor-intensive task that could not be accomplished easily. Land preparation, transplanting and harvesting are the expensive and time- consuming operations for successful rice cultivation. Tray soil

Labor cost accounts the biggest input cost for rice production (Clayton, 2010).

There is a need to explore establishment methods (EM) that require less labour but still allow the crop to be transplanted on time since labour scarcity has emerged as a serious problem in rice cultivation in Sri Lanka. Direct seeding (DS) is practiced as a solution but, apart from irregular stand establishment, the most disastrous constraint in DS is the invasion of weeds and weedy rice (Marambe 2009; Gunawardana et al., 2013). Use of herbicide in controlling weeds in DS is effective but excessive use is costly and causes problems such as ground water contamination, development of herbicide- resistant weed populations. Optimizing plant density and timeliness of operation is considered essential for optimizing yield in rice cultivation (Chaudhary et al., 2005). Hence, mechanical transplanting (MT) is one of the feasible alternatives in eliminating weed problem in DS and huge labour use in transplanting while facilitating the timeliness crop establishment.

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice

Industrialization, migration of agricultural labor to other job and high labor wage are the threat for sustainable rice production as well as food security. Labor crisis and high wage is particularly critical during peak labor-need periods, which typically occur during rice transplanting and harvesting. Tray soil

To overcome these, farm mechanization has been considered as an important remedial measure. In recent time, transplanting and harvesting machinery are considered top priority for sustainable rice production.

Agricultural machines have replaced human force in many rice cultivation practices such as land preparation, transplanting, harvest, and post-harvest process in many developed countries. Though land is Prepared mechanically but seedling raising and transplanting is still done traditionally in Bangladesh. About 156 man-days per hectare are required for producing rice. Forty five man-days are consumed for seedling raising and transplanting which is about 29% of the total labor requirement. Tray soil

Mechanisation of small holding will play an important role in increasing rice production.status and prostpectus

Manual paddy transplanting is the tedious, laborious and time consuming operations requiring about 250-300 man h ha-1 which is roughly 25% of total labor requirement of rice production [11]. Mufti AI, Khan AS. 1995. Performance evaluation of Yanmar paddy transplanter in Pakistan. Agricultural mechanization in Asia, Africa and Latin America. 26 (1): 31-36. status and prostpectus

At transplanting time, there is acute shortage of labour. This results in increased labour wages and a delayed transplanting operation. In some cases, a proper crop stand is not maintained by the hired labour. Hence there is an urgent need to have mechanization in rice production which will result in reducing the labour work and time consumed. Mechanical transplanting to release the work force and to reduce the cost of paddy production. Farmers are aware of the advantages associated with transplanting of paddy over the broadcasting. But they are unable to practice it for high scarcity of labor. The transplanting machines available in the country are imported. They are costly and unable to meet the plant geometry.

development and performance evaluation

Proper seed rate is not maintained and non uniform seed delivery observed many times. This leads to uneven plant stand.development and performance evaluation

basis. Manual transplanting takes longer period to complete transplanting operation. Therefore, major constraints are the high cost of manual transplanting and uneven plant population. Singh et al. (1985)studied the response of rice to different planting methods. development and performance evaluation

Timeliness of transplanting is essential for optimizing the yield and this can only be achieved through mechanical transplanting. A delay in transplanting reduces the yield. development and performance evaluation

t was reported that a delay in transplanting by one month reduces the yield by 25% and a delay of two month reduced the yield by 70% (Rao and Pradhan, 1973). There Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers field in Bangladesh

crisis of labour

Crisis of labor has created an unusual situation. The farm owners have to find the labors going door to door or they have to wait for the labors to finish the work in the nearby fields. Sometimes, they have to hire labor offering extra wages with additional facilities. As a result, the scheduled time of transplanting paddy expires in many places. Under such circumstances a less expensive and labor saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi et.al., 2004). Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers field in Bangladesh

Because of the good off-farm employment opportunities available in the area and the prevailing hot season, the persons already engaged in non-farm jobs are generally reluctant to perform rice transplantation.Therefore, frequent shortage of labour always has been reported during the season. The other common problems associated with the rice transplantation by hired labour are lower plant population per unit area, improper fixation of nursery plants in the soil, a higher percentage of missing plantation and un-even transplantation in paddy fields, i.e. dense and thin planted patches in the field. Diffusion Possibilities of Mechanical Rice Transplanters

The important reasons for low rice yield include water shortage, weed infestation, prevalence of insect pests and diseases and inappropriate sowing method leading to low plant population. Low plant population can be optimized using a proper sowing method.

Direct seeded rice: purely a site specific technology

Though a contract system for undertaking transplanting evolved during this period, the careless attitude of contract labourers (aggressive pulling of seedlings from the nursery, clipping seedlings and transplanting at more depth with insufficient plant density, etc) to complete the work in the shortest possible time has been affecting the productivity of rice in Bangladesh. Though the work standards have been declining, these contract labourers have started demanding higher wages every year.

Transplanting Rice Seedling Using Machine Transplanter : a Potential Step

The shifting agronomy to direct-seeded rice, necessitated by the

unavailability of labour for transplanting, has exacerbated weed problems such as Echinochloa spp. (Marambe and Amarasinghe, 2002), the sedges (Marambe, 2006) and weedy rice (Marambe and Amarasinghe, 2000; Marambe, 2005). In

WEEDY RICE: EVOLUTION, THREATS, AND MANAGEMENT B. Marambe Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

In rice, the planting methods have an impact on

the growth and yield besides cultivation cost and labour requirements

(Sanjitha

Rani and Jayakiran, 2010). “ DIGANG ” RICE ( Oryza sativa L .) UNDER UPLAND CONDITION OF BAWKU , UPPER EAST REGION , GHANA

No of seedlings per hill, depth, height of plants

Transplanting two to three seedlings per hill under normal conditions is enough. The use of more seedlings per hill, besides not being any additional advantage, involves an extra expense on seedlings. In case of transplanting with old seedlings, the number of seedlings per hill can be increased

The tiller buds formed at the basal node are not suppressed in case of shallow plantings . Therefore, the seedlings should be transplanted at 2 to 3 cm depth. Shallow planting gives better yields. The deeper planting results in an increased height of the plants besides delays and inhibits tillering. The

(Oryza sativa

Number of seedlings transplanted per hill

varies from country to country. While in

Burma, one to four seedlings are transplanted

per hill, in Sri Lanka only one seedling is

used. Usually, 5 to 7 seedlings are

transplanted in Philippines. Results in India

indicated that the number of fertile tillers

were greater with 3-4 seedlings

(Hedayetullaha, 1977).

Planting of different number of seedlings per

hill produced significant influence on rice

growth parameters. Planting of 3-4 seedlings

per hill recorded significantly higher plant

height

Maiti and Bhattacharya

(2011) and Rasool et al., (2013) who reported

that planting of fewer numbers of seedlings

enabled the plant to produce healthy

hill-1

leaves and tillers which had undergone

normal physiological growth and field

duration, resulting in more healthy leaf area

Growth and Yield of Machine Transplanted Rice ( Oryza sativa L .) as Influenced by Age and Number of Seedlings

water height. Seedling tray requirement depended on the space setting adjustment and seedlings dispensed per hill in the field. The tray requirement was reduced with higher space setting. Irrespective of space settings in the transplanter, mechanically transplanted rice produced the higher grain yield than the hand

adjustment and seedlings dispensed per hill in the field. The tray requirement was reduced with higher space setting. Irrespective of space settings in the transplanter, mechanically transplanted rice produced the higher grain yield than the hand transplanted rice. These findings revealed that wider spacing of mechanical transplanter (30 cm) along with tender seedlings

Irrespective of space settings in the transplanter, mechanically transplanted rice produced the higher grain yield than the hand transplanted rice. These findings revealed that wider spacing of mechanical transplanter (30 cm) along with tender seedlings helped to increase the grain yield.

transplanted rice. These findings revealed that wider spacing of mechanical transplanter (30 cm) along with tender seedlings helped to increase the grain yield. Keywords: Tender seedlings, plant

Seedlings dispensed in each stroke: The varietal difference caused variation of the seedlings density in tray which consequently affected the rate of seedlings dispensed per stroke indicated the increase in seedling tray requirement (Fig. 4). Islam (2016) stated that the main objectives

The varietal difference caused variation of the seedlings density in tray which consequently affected the rate of seedlings dispensed per stroke indicated the increase in seedling tray requirement (Fig. 4). Islam (2016) stated that the main objectives of mechanical transplanting are to faster in operation and avoid missing hill. Therefore, seedlings density setting should be

dispensed per stroke indicated the increase in seedling tray requirement (Fig. 4). Islam (2016) stated that the main objectives of mechanical transplanting are to faster in operation and avoid missing hill. Therefore, seedlings density setting should be adjusted to avoid the missing hill. At the same seedlings density setting, higher seedlings density in tray for BRRI dhan28

of mechanical transplanting are to faster in operation and avoid missing hill. Therefore, seedlings density setting should be adjusted to avoid the missing hill.

Plant to plant spacing: Plant spacing is the major

Plant to plant spacing: Plant spacing is the major driving factors affecting productivity. The distribution of plant to plant spacing in mechanically transplanted plot is presented in Fig. 5. Transplanter was operated in three space setting (18.5, 20.0 and 21.5 cm). In actual

Plant spacing is the major driving factors affecting productivity. The distribution of plant to plant spacing in mechanically transplanted plot is presented in Fig. 5. Transplanter was operated in three space setting (18.5, 20.0 and 21.5 cm). In actual field condition, plant spacing was not confined on the setting value due to slippage and skidding of the transplanter. Soil

transplanted plot is presented in Fig. 5. Transplanter was operated in three space setting (18.5, 20.0 and 21.5 cm). In actual field condition, plant spacing was not confined on the setting value due to slippage and skidding of the transplanter. Soil settlement in puddled soils also influenced the plant to plant spacing. The distance between plants determined the tray

field condition, plant spacing was not confined on the setting value due to slippage and skidding of the transplanter. Soil settlement in puddled soils also influenced the plant to plant spacing. The distance between plants determined the tray requirement in a transplanting operation and controlled by the space setting options depending on the seedlings density in

settlement in puddled soils also influenced the plant to plant spacing. The distance between plants determined the tray requirement in a transplanting operation and controlled by the space setting options depending on the seedlings density in trays. In mechanically transplanted plots, plant to plant spacing was obtained between 17-20 cm which was depended mostly

requirement in a transplanting operation and controlled by the space setting options depending on the seedlings density in trays. In mechanically transplanted plots, plant to plant spacing was obtained between 17-20 cm which was depended mostly on soil type, soil settling time, water height and depth of puddling. In manually transplanted plots, plant spacing varied from

trays. In mechanically transplanted plots, plant to plant spacing was obtained between 17-20 cm which was depended mostly on soil type, soil settling time, water height and depth of puddling. In manually transplanted plots, plant spacing varied from 27 × 25 cm.

on soil type, soil settling time, water height and depth of puddling. In manually transplanted plots, plant spacing varied from 27 × 25 cm.

Grain yield influenced by rice transplanter: Effect of plant spacing on grain yield: Grain yield is a function of inter play

Effect of plant spacing on grain yield: Grain yield is a function of inter play of various yield components such as number of productive tillers, spikelets panicle-1 and 1000 grain weight (Partha and Haque, 2011). The line to line spacing was fixed to 30 cm and plant to plant spacing can

Grain yield is a function of inter play of various yield components such as number of productive tillers, spikelets panicle-1 and 1000 grain weight (Partha and Haque, 2011). The line to line spacing was fixed to 30 cm and plant to plant spacing can be varied in mechanical transplanter. During transplanting, three seedlings interval setting (18.5×30, 20×30 and 21.5×30 cm)

and 1000 grain weight (Partha and Haque, 2011). The line to line spacing was fixed to 30 cm and plant to plant spacing can be varied in mechanical transplanter. During transplanting, three seedlings interval setting (18.5×30, 20×30 and 21.5×30 cm) was applied from space setting panel of the transplanter. Yield data of those plots in respect to space setting were compared

be varied in mechanical transplanter. During transplanting, three seedlings interval setting (18.5×30, 20×30 and 21.5×30 cm) was applied from space setting panel of the transplanter. Yield data of those plots in respect to space setting were compared with manually transplanted rice. It was observed that yield was slightly increased with the increase in plant to plant space

was applied from space setting panel of the transplanter. Yield data of those plots in respect to space setting were compared with manually transplanted rice. It was observed that yield was slightly increased with the increase in plant to plant space setting (Fig. 8). El-Kassa by et al. (2012) conducted field experiment on plant density and seedlings age on two cultivars in

with manually transplanted rice. It was observed that yield was slightly increased with the increase in plant to plant space setting (Fig. 8). El-Kassa by et al. (2012) conducted field experiment on plant density and seedlings age on two cultivars in Egypt

transplanted rice for both the variety due to use of tender aged seedlings (Fig. 10). This result is in accordance with the findings of Islam (2016) and Islam et al. (2016b). Makarim et al. (2002) stated that the performance of tender aged seedlings showed better than older seedlings. Tillering influenced the panicle intensity as well as grain yield of rice (Quyen et al.,

findings of Islam (2016) and Islam et al. (2016b). Makarim et al. (2002) stated that the performance of tender aged seedlings showed better than older seedlings. Tillering influenced the panicle intensity as well as grain yield of rice (Quyen et al., 2004). McHugh et al. (2002) and Thiyagarajan et al. (2002) observed that 8-15 day and 10-day old seedlings transplanted at

showed better than older seedlings. Tillering influenced the panicle intensity as well as grain yield of rice (Quyen et al., 2004). McHugh et al. (2002) and Thiyagarajan et al. (2002) observed that 8-15 day and 10-day old seedlings transplanted at 25 hills m−2 showed the highest grain yield in Madagascar and Sumatra. Krishna and Biradarpatil (2009) observed high grain

2004). McHugh et al. (2002) and Thiyagarajan et al. (2002) observed that 8-15 day and 10-day old seedlings transplanted at 25 hills m−2 showed the highest grain yield in Madagascar and Sumatra. Krishna and Biradarpatil (2009) observed high grain yields of 3.25 t ha-1 with 12-day old seedlings than 8-, 16- and 25-day old seedlings and the yield decline of seedlings of latter

25 hills m−2 showed the highest grain yield in Madagascar and Sumatra. Krishna and Biradarpatil (2009) observed high grain yields of 3.25 t ha-1 with 12-day old seedlings than 8-, 16- and 25-day old seedlings and the yield decline of seedlings of latter three ages was primarily attributed to the reduction in the number of tillers. Younger seedlings could relieve the transplanting

yields of 3.25 t ha-1 with 12-day old seedlings than 8-, 16- and 25-day old seedlings and the yield decline of seedlings of latter three ages was primarily attributed to the reduction in the number of tillers. Younger seedlings could relieve the transplanting stress in a shorter period of time compared to that of older seedlings due to the higher nitrogen content in the former

three ages was primarily attributed to the reduction in the number of tillers. Younger seedlings could relieve the transplanting stress in a shorter period of time compared to that of older seedlings due to the higher nitrogen content in the former (Yamamoto et al., 1998), and the plants’ ability to faster resumption of the rate of phyllochron development (Anonymous,

stress in a shorter period of time compared to that of older seedlings due to the higher nitrogen content in the former (Yamamoto et al., 1998), and the plants’ ability to faster resumption of the rate of phyllochron development (Anonymous, 2004).

(Yamamoto et al., 1998), and the plants’ ability to faster resumption of the rate of phyllochron development (Anonymous, 2004).

Effect of row spacing of Rice transplanter on seedling requirement and grain yield

### **2.51Wet bed for Random transplanting**

Wet-bed nursery The wet-bed nursery is mainly used in areas where there is enough water. Pre-

germinated seeds are broadcasted on a soil that is thoroughly puddled and leveled. Drainage canals for proper removal of water must be constructed. Addition of organic manure (decomposed) and small amounts of inorganic fertilizer as basal dressing will increase easiness of uprooting of seedlings and seedling vigor. Total seed bed area is about 1/10 of the area to be transplanted and requires about 100 kg of seed paddy per ha. Development and performance of

### **2.52 Parachute method**

A recently developed method for rice transplantation “parachute method” however, over-comes some of these problems in the two traditional methods. It requires less labour, less time and is more efficient. Other

advantages are good and quick stand

establishment, higher tillering and thus higher paddy yield. However, parachute method of rice transplanting requires more skilled labour for nursery raising and transplanting. This study reports a comparison and an

COMPARISON OF DIFFERENT PLANTING METHODS FOR OPTIMIZATION OF PLANT POPULATION OF FINE RICE ( Oryza sativa L .) IN PUNJAB ( PAKISTAN )

#### **2.531 Transplanters**

Mechanisation is needed to raise productivity in rainfed upland and rainfed lowland and to increase cropping intensity in irrigated farms

The manual and self propelled transplanter reduces cost of transplanting by 45-50% and labour requirement by 75-80%.

status and prospectus of

Mechanization decreases

cost of production by reducing labour needed for

particular operation and economy of power and other

inputs (Das, 2012) Study of Adoption of Mechanical Rice Transplanters through Custom Hiring in Tamil Nadu-

a Case Study

Paddy Transplanter Machine transplanting using rice transplanters requires considerably less time

and labor than manual transplanting. It increases the approximate area that a person can plant from 0.7 to 1ha/day. Transplanting of paddy seedlings can be categorized into three groups as follows: 1. By hand (manual) 2. Manually operated machines (work by man power) 3. Mechanically operated machines (work by engine power) development and performance evaluation

Mohanty et al. (2010) reported that the inadequate number of hills per hectare

transplanted by manual labour and the delay in transplanting due to labour shortage during peak transplanting season pushed the demand for a mechanical transplanting. development and performance evaluation

Rice transplanting was mechanized by 1970s and 1980s in Japan and Korea, respectively (Haytham et al., 2010). They also developed new technologies of seedling raising for rice transplanter (Tasaka et al., 1996). Now more than 99% of paddy fields are cultivated by mechanized transplanting in both countries. Mechanical rice transplanting is being introduced in Bangladesh and gaining popularity through the different intervention of some governmental and non-governmental organizations. Usually, a plastic tray called a nursery box (58 × 28 × 2.5cm) is used for raising rice seedlings. Soil is packed into it, and seeds are sown. Nursery boxes are then arranged plain land and the seedlings are raised. When the seedlings are sufficiently grown, the nursery boxes are put on a van and taken to the paddy fields. The seedlings are then transplanted by a transplanter (Haytham et al., 2010). But many technical issues must be considered for successful operation of rice transplanter. For example, in machine transplanting, seedling should be raised with special care in tray. Raising seedling for transplanting requires suitable seedling age, materials and advanced practices including tray and nursery bed soil, seed

preparation for pre-germination and disease disinfection. About 3 leaf stage and 12 to 15cm height seedlings are required for machine transplanting (Kitagawa et al., 2004). **Tray soil**

Transplanters types -status and prostpectus of mechanization of rice

Techno-Economic Performance of a Self-Propelled Rice Transplanter and Comparison with Hand Transplanting for Hybrid Rice Variety

Paddy transplanter Transplanter is a machine used to transplant matured (15-21days) paddy

seedlings at proper place, at right time into the puddled field. A common paddy transplanter comprises; a seedling tray on which mat type rice nursery is kept; a seedling tray shifter that shifts the seedling tray and pickup forks with needles that pick up a seedling from mat type nursery on the seedling tray and put the seedling into the puddled soil. The float of the transplanter served as a base and also helps in movement of the machine over excess water in the field. It creates 2-3 cm raised bed for placement of seedlings at 4-5 cm depth. It also serves as a platform for placement of nursery during transplanting operation. Eight row as well as four row commercially available self propelled transplanter

development and performance

About the transplanter we used

Within row space (WRS) 12 cm, 14 cm, 16 cm, 18 cm, 21 cm

per hill number of seedlings

Planting depths (PD) 1.5 cm , 2 cm, 2.3 cm, 2.7 cm, 3 cm, 3.7 cm

Use of higher WRS (18 cm or 21 cm) or lower number of PHSN (4) did not affect the yield. This study also proves the feasibility of using a wider range of pds (1.5-3.7 cm) in MT

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice

#### 

#### **2.532 Problems with Mechanical Transplanting**

However, rice transplanters are considerably expensive for almost all Asian small-hold farmers. It is popular in industrialized countries where labor cost is high, for

The farmer of Bangladesh does not give attention to the age of seedlings at transplanting and use 30 or more day’s age of seedling. For optimum yield, age

Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers field in Bangladesh

The rice mechanization can be

further increased by following the steps are listed below

a)

Subsidized transplanting machinery

.

b)

Subsidized

nursery sowing machine and nursery

centers.

c)

Providing

incentive to farmer for mechanized

transplanting.

d)

T

raining women SHGs to use transplanting machinery

in order to ensure alternative employment.

e)

Setting

up separate training center to train operators or

initiating apprentice training under government subsidy.

f)

Ensuring only proven machinery

that are reliable,

serviceable and having adequate service facility.

**Earlier problems in india**

**1 For instance, from researchers' point of view, poor anchoring of**

**seedlings in the soil, uprooting of seedlings by the wave action produced due to the movement of the machine, poor metering of seedlings ranging from 3 to 11 seedlings per hole, 35-55% missing plantation were the major problems diagnosed. From farmers' perspectives, it was difficult for them to maintain 2-4 inches water depth in the field, farmers' fields are also not precisely leveled and they do not like seedling preparation operation as it was time consuming and laborious (IRRI-PAK Agricultural Machinery Program, 1978; Khan et al., 1979).** Diffusion Possibilities of Mechanical Rice Transplanters

**the main advantage of the mechanical transplanting reported the farmers was that the nursery plants are firmly pegged into the soil, provided that the field is precisely or laser levelled. In case of poor levelling, uniform transplantation is not possible.**

**Cutting nursery according to the size of feeding trays and its transportation is a tough job, 3. Raising nursery for a very large paddy area is very costly, 4.**

**The presence of pebbles in the roots of the nursery often damages the plants and breaks the pegging needles of the machine**

**the innovator farmers reported that mechanically transplanted fields yielded 200-240 kg acre-1 higher as compared with the manually transplanted fields at similar inputs use level. But the problem is the price of the transplnter is high and the farmers has to spend more money on the rental of the transplnter but even though the can gain more harvest than the manual transplanting of rice.** **This implies that a significant increase in paddy production can take place by wide spread adoption of mechanical transplanters in the area. And also supplying transplnters by the governemt free of charge**

**It is also needed to search for alterations in the machine to deal with the problem of pebbles in the soil.**

Diffusion Possibilities of Mechanical Rice Transplanters

**Adoption to MT is still low due to socio-economic reasons and lack of technical information available.**

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice

**Presently, MT is promoted in Yaya 2 program which is implemented**

**by the Department of Agriculture (DOA), Sri Lanka. Further, the Food Production National Programme implemented by the Ministry of Agriculture is aiming to enhance the productivity of rice up to 5 t/ha in year 2018 where MT is identified as one of the main area to be exploited. Despite with many advantages, farmers are still reluctant to adopt MT because of some socio- economic reasons and lack of technical specifications available related to agronomic management options of the transplanter. Problems in nursery preparation, selecting suitable varieties and appropriate planting spaces have been reported and a trend in giving up the use of mechanical transplanter in rice cultivation has been observed. Studies on efficient use of mechanical transplanter to optimize the growth and yield of rice have not yet been properly investigated in Sri Lanka.**

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted

**Though the farmers were experienced in rice cultivation, they mostly lacked knowledge on farm mechanization.**

Transplanting Rice Seedling Using Machine Transplanter : a Potential Step

**Rice transplanting using machine transplanter is technologically viable and economically feasible. But the cost of 4 rows machine transplanter is high (approximately 200000 BDT or 2500 US$) and this constrain smallholder farmers from adopting this technology. However some of the following measures can enhance adoption. Government may enhance the subsidy component for promoting this technology from 50 to 75 per cent so that every farmer could afford a machine transplanter and can do timely operations**

**? A healthy agricultural mechanization policy must be formulated immediately including machine development and manufacturing, quality protection by standardization of machines, skill development of researchers, farmers, mechanics and machine operators and marketing system improvement**

**? Funds for relevant machinery research, development and extension are to be provided to the capable institutions including selected Agricultural Research Institutes and Universities on competitive basis. This stimulates quality research to produce new machines within possible shortest time. Also it enhances farm activities and agricultural machinery industries.**

**Before distributing these implements to farmers, efforts should be made to build the knowledge and skills of extension functionaries on use of these implements**

Transplanting Rice Seedling Using Machine Transplanter : a Potential Step

Seedlings raising is a crucial part of mechanical transplanter. Farmers do not know how to raise seedlings suitable for mechanical

Effect of row spacing of Rice transplanter on seedling requirement and grain yield

**2.6 Seeding rate**

**The amount of seed was 130g (dry) and 150g (sprouted) per tray. Tray soil**

**The number of seedlings per hill in rice transplanter increased from 1.7 to 2.8 as the seeding rate increased from 60 to 100 g per tray. The missing hills decreased from 13.32 to 7.65 % with increasing seeding rate from 60 to 100 g per tray**

**total cost of transplanting in the treatments of T2, T3 and T4 was decreased by 19.20, 22.44 and 25.70%, respectively as compared to hand transplanting** Techno-Economic Performance of a Self-Propelled Rice Transplanter and Comparison with Hand Transplanting for Hybrid Rice Variety

**60, 80 and 100 g per tray.** Techno-Economic Performance of a Self-Propelled Rice Transplanter and Comparison with Hand Transplanting for Hybrid Rice Variety

**number of seedlings per hill in rice transplanter increased from 1.7 to 2.8 as the seeding rate increased from 60 to 100 g per tray. The average number of seedlings per hill in rice transplanter was obtained to be 2.2 compared to 1.1 in hand transplanting.**

Techno-Economic Performance of a Self-Propelled Rice Transplanter and Comparison with Hand Transplanting for Hybrid Rice Variety**60**

**The seed rate per tray for mechanical transplanting was 130-140 gm dry seed.** Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers field in Bangladesh

**Rice plants significantly reduce the yield after transplanting seedlings grown at higher seed rate as compared to seedlings grown with low seeding density (Singh et al., 1987).**

**Mostly farmers use high seed rates in the nursery to avoid weed competition and to uproot seedlings easily, but they don’t realize its effect after transplanting in main field**

**Transplanting shock was also higher in older seedlings grown with high seed rate due the more root damage during up- rooting, as separation of seedlings caused maximum root damage during uprooting and at the time of transplanting in main field. Our results are in line with the explanations of some previous studies (Singh et al., 2005; Lal and Roy, 1996; Panda et al., 1991) who reported that seedlings grown with low seed rate and with fertilizer application increased vigor, showing a better stand in main field after transplanting and ultimately effected growth and yield of rice crop**

Influence of Nursery Management and Seedling Age on Growth and Economic Performance of Fine Rice

**seeds or 4 seed /m2. When farmers direct seed their crops, only 10‐20% of the seeds sown will actually established. In a nursery, this may increase to 40‐50%.**

Rice Production Manual

**The seed rate naturally influences the growth of the seedlings. Thin sowing gives strong and tillered seedlings, whereas thick sowing provides thin and tall seedlings without tillers. Thin sowing in nurseries is always better and it will produce strong and sturdy seedlings, which can withstand adverse climatic conditions better and produce better yields. Therefore,**

(Oryza sativa

**and BRRI dhan48 were transplanted in the farmer’s field by mechanical rice transplanter and compared with hand transplanting. Seedlings density was reduced at the seed rate higher than 145 gm tray-1 indicating higher seed rate increased the seedlings mortality. Seedlings mat prepared**

**in the farmer’s field by mechanical rice transplanter and compared with hand transplanting. Seedlings density was reduced at the seed rate higher than 145 gm tray-1 indicating higher seed rate increased the seedlings mortality. Seedlings mat prepared by the farmers were varied in seedling height, density and color due to management skill of the**

Effect of row spacing of Rice transplanter on seedling requirement and grain yield

**Seedlings density depended on the seeding rate, germination and uniform placement of seed during tray preparation. Seedlings density followed increasing trend with**

**Seed rate applied by the respective farmers was ranged from 125 to 150 gm tray-1. Seedlings density depended on the seeding rate, germination and uniform placement of seed during tray preparation. Seedlings density followed increasing trend with the increase in seed rate up to 145 gm tray-1 (Fig. 1). Seedlings mortality increased in higher seed rate and reduced the**

**rate, germination and uniform placement of seed during tray preparation. Seedlings density followed increasing trend with the increase in seed rate up to 145 gm tray-1 (Fig. 1). Seedlings mortality increased in higher seed rate and reduced the seedling density in seedling tray (Hossen, 2016). The amount of seed used in tray preparation varied depending on the variety**

**the increase in seed rate up to 145 gm tray-1 (Fig. 1). Seedlings mortality increased in higher seed rate and reduced the seedling density in seedling tray (Hossen, 2016). The amount of seed used in tray preparation varied depending on the variety and germination rate. Seed rate was also varied from one farmer to another due to farmer’s perception. Amount of seed used**

**seedling density in seedling tray (Hossen, 2016). The amount of seed used in tray preparation varied depending on the variety and germination rate. Seed rate was also varied from one farmer to another due to farmer’s perception. Amount of seed used per tray by different farmers had direct influence on the seedlings density obtained per tray and consequently tray**

**and germination rate. Seed rate was also varied from one farmer to another due to farmer’s perception. Amount of seed used per tray by different farmers had direct influence on the seedlings density obtained per tray and consequently tray requirement in the field. Islam et al. (2015) mentioned that tray requirement, number of seedlings dispensed per stroke and**

**per tray by different farmers had direct influence on the seedlings density obtained per tray and consequently tray requirement in the field. Islam et al. (2015) mentioned that tray requirement, number of seedlings dispensed per stroke and missing hill during transplanting operation were subjected to the seed rate and uniformity of seedlings establishment.**

**requirement in the field. Islam et al. (2015) mentioned that tray requirement, number of seedlings dispensed per stroke and missing hill during transplanting operation were subjected to the seed rate and uniformity of seedlings establishment.**

Effect of row spacing of Rice transplanter on seedling requirement and grain yield

## **2.7 Seedling Vigor**

Seedling vigor is defined as the plant’s ability to emerge rapidly from soil or

water and cover the ground fast (Fukai, 2002).

Seedling vigor is the basic component of the transplanted rice, which depends on its growing environment and proper age. Influence of Nursery Management and Seedling Age on Growth and Economic Performance of Fine Rice

Success of transplanted rice directly correlate with the nursery seedlings as it plays major role for establishment in the main field (Padalia, 1980).

Transplanting of healthy seedlings grown at proper nitrogen application at nurserybedshowed better paddy yield (Panda et al., 1991 and TeKrony and Egli, 1991).

Healthy and vigorous seedlings from nursery-bed will give good results after transplanting in the main fiel

Increase in growth rate might be due to the better seedling vigor. Seedlings grown with high seeding density and without fertilizer appli- cation decreased vigor due to high seedling competition, which ultimately gave a weaker start to crop.

Influence of Nursery Management and Seedling Age on Growth and Economic Performance of Fine Rice

The optimum SA was identified as 12 days, but seedlings from 9 to 15 days can be also used without any yield decline

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice

Early vigor is associated with rapid crop establishment which is important in increasing the ability of rice to compete against weeds. Rice competitiveness with weeds, as either the ability to suppress weeds or the ability to avoid being suppressed by weeds (Goldberg and Landa, 1991; Namuco, et al.,

3

2009), o Early Vigor Traits in Selected Upland and Rainfed Lowland Rice ( Oryza sativa L .) Genotypes

Thus, dry weight could be used as a basis in defining early vigor

Good seedling vigor is also another trait that could increase yield of upland rice.

Early Vigor Traits in Selected Upland and Rainfed Lowland Rice ( Oryza sativa L .) Genotypes

## **2.8 Growth parameters of seedlings**

Dry weight is associated with the accumulation of food reserves during early crop

establishment. Several studies suggested that dry weight is a useful tool in defining early vigor.

Early Vigor Traits in Selected Upland and Rainfed Lowland Rice ( Oryza sativa L .) Genotypes

## **2.9 Early Growth parameters of rice plants**

MT produced a comparatively lower ground cover %, but had higher tiller and panicle densities with 9-22 % yield advance compared to CT. Heading and maturity was delayed by 3-5 days in MT compared to the CT

Ground cover increased above 50 % at the 4th week after planting (WAP) in both establishment methods, but was always higher in CT compared to MT (Figures 1A, 1B, 1C and 1D). It reached above 80 % at the end of vegetative stage in CT. It was also observed that a higher ground cover % was achieved by 4-4½ months age varieties compared with 3-3½ months age varieties since the former have longer vegetative periods. Thus, MT may be more adaptable for rice varieties having longer vegetative period.

Tiller density (expressed as number/m2) under MT was significantly

higher than in CT

Irrespective with the lesser number of hills/m2 established in MT than that of in CT, high densities of tillers and panicles of MT were attributed by the production of higher number of tillers and panicles/hill compared to CT. MT produced an average of 18 tillers/hill compared to 13 The production of higher tiller and panicle/hill in MT may be due to the maintenance of uniform planting density during the establishment compared with irregular random planting in CT.

Table

Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice

The number of active tillers and panicles produced will be the major determinate of crop yield. Therefore the number of seedlings established must be sufficient to produce the desired number of tillers and panicles.

Each seedling will develop 3‐10 tillers depending the nutrient status, variety and planting rate and spacing. Higher seeding rates normally give fewer tillers per plant. Transplanted crops generally produce more tillers than direct seeded crops, and dry season crops often produce more tillers than wet season crops.

Three seedlings per hill is normal in most countries.

Rice Production Manual

Plant height was affected significantly by different sowing methods.

Number of panicle bearing tillers was influenced significantly by various sowing methods

Less number of panicle bearing tillers in direct seeding may again be explained in terms of availability of moisture and nutrients to the crop plants at the panicle initiation stage. The availability of moisture and nutrients was low due to lack of proper distance and more number of weeds in direct sowing. Moreover roots of plant could not penetrate deep enough to exploit the soil resources fully, giving a fair chance to the weeds to compete with the crop plant. Similar results were reported by Naklange et al. (1996).

The higher number of tillers in parachute compared to the other methods of direct seeding might be attributed to the availability of sufficient amount of nutrients and moisture at tillering initiation stage due to the deep placement of seedling and better establishment of roots. Secondly, this method had no transplanting shock as it had a mud ball along its roots, hence started growth one week earlier. Availability

COMPARISON OF DIFFERENT PLANTING METHODS FOR OPTIMIZATION OF PLANT POPULATION OF FINE RICE ( Oryza sativa L .) IN PUNJAB ( PAKISTAN )

% ground covers by beaded string method

? % ground covers by beaded string method at weekly interval till varieties reach 100% ground cover. First reading can be started at 12-15 DAS. For this, you have to make 20 knots at equal distance (10-cm apart). So the string will be 2-m long with 20 knots at 10-cm apart. Hold the string diagonally at two locations in a plot and see how many knots (if looking perpendicularly from top) are directly hitting the crop canopy (See figure below). Multiply no. of knots hitting canopy by 5 to estimate % ground cover. For example, if 5 knots hits canopy, then % ground cover would be 25%.

% ground covers by beaded string method

Agrochemical pesticides and kidney related diseases, Sri Lanka | EJAtlas [WWW Document], 2016. URL https://ejatlas.org/conflict/agrochemical-pesticides-and-kidney-related-diseases-in-sri-lanka (accessed 12.1.18).

Akbar, N., Jabran, K., Habib, T., 2007. Comparison of different Planting Methods for Optimization of plant population of fine rice ( Oryza sativa L .) in Punjab (Parkistan) 44, 597–599.

Alizadeh, M.R., Yadollahinia, A.R., Rahimi-AjdadiI, F., 2011. Techno-Economic Performance of a Self-Propelled Rice Transplanter and Comparison with Hand Transplanting for Hybrid Rice Variety 5, 27–30.

Baloch, A.W., Soomro, A.M., Javed, M. a., Ahmed, M., Bughio, H.R., Bughio, M.S., Mastoi, .N. N., 2002. Optimum Plant Density for High Yield in Rice (Oryza sativa L.). Asian J. Plant Sci. 1, 25–27. https://doi.org/10.3923/ajps.2002.25.27

Bandara, R.M.U.S., Silva, Y.M.S.H.I.U. De, Dissanayaka, H.M.M.K.K.H., 2017. Rice Varieties Suitable for Machine Transplanting in Rajanganaya. Open. Minds Res. Sustain. Dev. 407–409.

Caton, B.., Foin, T.., Hill, J.., 1999. A plant growth model for integrated weed management in direct-seeded rice. III. Interspecific competition for light. F. Crop. Res. 63, 47–61. https://doi.org/10.1016/S0378-4290(99)00026-X

CBSL, 2018. Economics and Social Statistics of Sri Lanka.

CBSL, 2017. National Output, Expenditure and Income.

Clayton, S., 2010. 50 years of Rice Science for a better world-and it’s just the start. Rice Today,IRRI pp.12.

Columbia, B., Division, A., 2013. Tray Soil Management in Raising Seedlings for Rice Transplanter 7, 2481–2489.

Das, F.C., 2012. Status and prospects of mechanization in rice. Rice Knowl. Manag. P ortal,〈 http//www. rkmp. co. 753006, 1–24.

Department of census and statistics, 2016. Paddy statistics 2015/2016 Maha season.

Desai, K.S., 2012. Development and Performance Testing of Two Row Paddy Transplanter. College of Agricultural Engineering and Technology.

Deseo, N., 2012. Early Vigor Traits in Selected Upland and Rainfed Lowland Rice (Oryza sativa L.) Genotypes.

Dhanapala, M.P., 2000. Bridging the Rice Yield gap in Sri Lanka, in: Papademetriou, M.K., Dent, F.J., Herath, E.M. (Eds.), Bridging the Rice Yield Gap in the Asia Pacific Region. FAO, Bangkok, Thailand, pp. 135–146.

Dushani, A.L., Sandika, S.N., 2009. Growth Performance of Rice Sector : the Present Scenario in Sri Lanka. Trop. Agric. Res. Ext. 12, 71–76.

Fan, Y., Song, Y., Septiningsih, E.M., Prasetiyono, J., Lubis, E., Tai, T.H., Tjubaryat, T., Moeljopawiro, S., McCouch, S.R., 2003. IPGWAS : An Integrated Pipeline for Genome-Wide Association Studies User Manual Li Ka Shing Faculty of Medicine The University of Hong Kong control and association analysis of genome-wide genetic studies . Biochemical and. Theor. Appl. Genet. 107, 363–368. https://doi.org/10.1073/pnas.1317360111.

FAO Sri Lanka, 2012. FAO Country Programming Framework 2013-2017 Sri Lanka.

Farooq, U., Sheikh, A.D., Iqbal, M., Bashir, A., Anwar, Z., 2001. Diffusion Possibilities of Mechanical Rice Transplanters. Int. J. Agric. Biol. 17–20.

Food and Agriculture Organization of the United Nations, 2000. Bridging the rice yield gap in the Asia-Pacific Region, FAO. Bangkok, Thailand.

Gaikwad, P.B., Shahare, P.U., Pathak, S. V, Aware, V. V, 2015. Development and performance evaluation of four row self propelled paddy transplanter. Int. J. Agric. Eng. 8, 9–14. https://doi.org/10.15740/HAS/IJAE/8.1/9-14

Gunawardana, W.G.N., Ariyaratne, M., Bandaranayake, P., Marambe, B., 2013. Control of Echinochloa colona in aerobic rice: effect of different rates of seed paddy and post-plant herbicides in the dry zone of Sri Lanka. role weed Sci. Support. food Secur. by 2020. Proc. 24th Asian-Pacific Weed Sci. Soc. Conf. Bandung, Indones. Oct. 22-25, 2013 431–437.

Hassan Akhgari, 2011. Assessment of direct seeded and transplanting methods of rice cultivars in the northern part of Iran. African J. Agric. Reseearch 6. https://doi.org/10.5897/AJAR11.973

Hayleys empowers greater productivity via mechanised rice transplanter | FT Online [WWW Document], 2013. URL http://www.ft.lk/agriculture/hayleys-empowers-greater-productivity-via-mechanised-rice-transplanter/31-188536 (accessed 12.1.18).

Henegedara GM, 2002. Agricultural Policy reforms in paddy sector in Sri Lanka. An over view. Sri Lankan, J. Agrar. Stud. 10, 26–34.

Hill, J.E., Bochchi, S., Clampet, W.S., Bayen, D.E., 1990. Direct seeded rice in the temperate climates of Australia, Italy and the United Satates, in: Direct Seeded Flooded Rice in the Tropics. IRRI, Seoul,Korea, pp. 91–102.

Himeda, M., 1994. Cultivation technique of rice nurseling seeding: Review of research papers and its future implementation. Agric. Hortic. 69, 679–683, 791–796.

Hossain, M.F., Sallam, M.A., Uddin, M.R., Pervez, Z., Sarkar, M.A.R., 2002. A Comparative Study of Direct Seeding Versus Transplnting Method on Yield of Aus Rice. J. Agron. 1, 86–88.

Illangakoon, T.K., Piyasiri, C.H., Kumar, V., 2017. Impact of varieties, spacing and seedling management on growth and yield of mechanicaly transplanted rice 112–128.

Iqbal, M.F., Hussain, M., Rasheed, A., 2017. Direct seeded rice: purely a site specific technology. Int. J. Adv. Res. Biol. Sci. 4, 53–57. https://doi.org/10.22192/ijarbs

IRRI, 2007. Rice Production Manual 14.

IRRI Rice Knowledge Bank, 2018. Direct seeding - IRRI Rice Knowledge Bank [WWW Document]. URL http://www.knowledgebank.irri.org/step-by-step-production/growth/planting/direct-seeding#wet-direct-seeding (accessed 11.28.18).

Islam, A., Rahman, M., Rahman, A., Islam, M., Rahman, M., 2016. Techno-economic performance of 4-row self-propelled mechanical rice transplanter at farmers field in Bangladesh. Progress. Agric. 27, 369. https://doi.org/10.3329/pa.v27i3.30834

Islam, A.K.M.S., Islam, M.T., Rabbani, M.A., Rahman, M.A., Ziaur Rahman, A.B.M., 2015. Commercial mechanical rice transplanting under public private partnership in Bangladesh. J. Biosci. Agric. Res. 6, 501–511. https://doi.org/10.18801/jbar.060115.60

Islam, A.K.M.S., Khan, M.A.I., 2017. Effect of row spacing of Rice transplanter on seedling requirement and grain yield. Int. J. Sci. Technol. 44, 2562–2573.

Lal, M., Roy, R.K., 1996. Effect of nursery seeding density and fertilizer on seedling growth and yeild of rice (Oryza sativa). Int. J. Agron. 41, 642–644.

Louisiana, A., 2009. Plant materials technical note no. 11. Tech. Notes.

Mabbayad, B.B. and, Bordo, R.A.O., 1971. Transplanting vs. direct seeding. World Farming 13, 6–7.

Mahbubur Rashid, M., Ahmed, A., Ul Kabir, A., 2015. Transplanting Rice Seedling Using Machine Transplanter: a Potential Step for Mechanization in Agriculture.

Manjappa, K., Kataraki, N.G., 2004. Use of Drum Seeder and Transplanter for Increasing Rice Profitability 17.

Marambe, B., 2009. WEEDY RICE: EVOLUTION, THREATS, AND MANAGEMENT B. Marambe Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka. Trop. Agric. 157, 0–15.

MoADR, 1989. Agricultural implementation programme. Peradeniya, Sri Lanka.

Oparka, K.J., Gates, P.J., 1982. (Oryza sativa 43, 108–109.

Panda, M.M., Reddy, M.D., Sharma, A.R., 1991. Yield performance of rainfed lowland rice as affected by nursery fertilization under conditions of intermediate deep water (15-50cm) and flash flood. Plant Soil 132, 65–71.

Pandey, S., Mortimer, M., Wade, L., Tuong, T.P., Lopez, K., Hardy, B., 2000. Direct seeding:research issues and opportunities. Proc. Int. Work. direct seeding Asian rice Syst. Res. issues Oppor. Work. direct seeding Asian rice Syst. Res. issues Oppor. 383.

Pathinayake, B.D., Nugaliyadde, L., Sandanayake, C.A., 1990. Direct Seeding practices for Rice in Sri Lanka, in: Direct Seeded Flooded Rice in the Tropics. IRRI, Seoul,Korea, pp. 77–90.

Perera, B.M.K., Dhanapala, M.P., Wickremasinghe, D.B., Fazekas, C., Wetselaar, R., 1990. Agronomic aspects of the rice yield gap between farmer and researcher, in: Menz, K.M. (Ed.), Rice Production in Sri Lanka, A Combined Agronomic/Economic Study in the Internlediate and Dry Zones. Australian Centre for International Agricultural Research, Canberra, pp. 10–20.

Pradhan, S., Mohanty, S.K., 2014. Ergo-Economical Analysis of Different Paddy Transplanting Operations in Eastern India. IOSR J. Agric. Vet. Sci. 6, 2319–2372.

Rajapakse, S., Shivanthan, M.C., Selvarajah, M., 2016. Chronic kidney disease of unknown etiology in Sri Lanka. Int. J. Occup. Environ. Health 22, 259–264. https://doi.org/10.1080/10773525.2016.1203097

Rani, T.S., Jayakiran, K., 2010. Evaluation of different planting techniques for economic feasibility in rice. Electron. J. Environ. Agric. Food Chem. 9(1), 150–153.

Ratnasekera, D., 2015. Weedy rice: A threat to rice production in Sri Lanka. J. Univ. Ruhuna 1, 2–13. https://doi.org/10.1016/j.electacta.2007.04.013

Rice Research & Development Institute Bathalagoda, 2017. Rice Cultivation [WWW Document]. URL http://doa.gov.lk/rrdi/index.php/en/crop/42-crop-rice-cultivation (accessed 8.28.18).

Rickman, J.F., Mussgnug, F., Khanda, C.M., Satpathy, S.D., Parida, N., Singla, K., Kumar, V., Banik, N.C., Iftikar, W., Mishra, A., Sudhir-Yadav, Kumar, V., Malik, R., McDonald, A., 2015. Operational manual for mechanical transplanting of rice 18 pages.

Sangeetha, C., Baskar, P., 2015. Influence of different crop establishment methods on productivity of rice–A Review. Agric. Rev. 36, 113. https://doi.org/10.5958/0976-0741.2015.00013.6

Sarwar, N., Ali, H., Maqsood, M., Ahmad, A., Ullah, E., Khaliq, T., Hill, J.E., 2014. Influence of Nursery Management and Seedling Age on Growth and Economic Performance of Fine Rice. J. Plant Nutr. 37, 1287–1303. https://doi.org/10.1080/01904167.2014.881490

Septiningsih, E.M., Prasetiyono, J., Lubis, E., Tai, T.H., Tjubaryat, T., Moeljopawiro, S., McCouch, S.R., 2003. Identification of quantitative trait loci for yield and yield components in an advanced backcross population derived from the Oryza sativa variety IR64 and the wild relative O-rufipogon. Theor. Appl. Genet. 107, 1419–1432. https://doi.org/10.1073/pnas.1317360111.

Singh, F., Kang, J.S., Singh, A., Singh, T., 2018. Productivity of mechanically transplanted rice ( Oryza sativa L .) as influenced by time of nitrogen application Productivity of Mechanically Transplanted Rice ( Oryza sativa L .) as Influenced by Time of Nitrogen Application 0–5.

Singh, K.N., Hassan, B., Kanday, B.A., Bhat, A.K., 2005. Effect of nursery fertilization on seedling growth and yield of rice. Indian J. Agron. 50, 187–189.

Singh, R.K., Pande, R.S., Namdeo, N.K., 1981. Response of Ratna to mathods of planting and nitrogen levels.Oryza. F. Crop. Res. 18, 182–183.

Sri Lanka as a Rice Exporting Country: Possibilities and Problems [WWW Document], 2011. URL http://www.ips.lk/talkingeconomics/2011/12/07/sri-lanka-as-a-rice-exporting-country-possibilities-and-problems/ (accessed 12.1.18).

Sri Lanka raises rice productivity with Korean technology [WWW Document], 2016. URL https://economynext.com/Sri\_Lanka\_raises\_rice\_productivity\_with\_Korean\_technology-3-5503.html (accessed 11.30.18).

Sri Lanka World Bank Group, 2008. Appendix 6 : Sri Lanka.

Tekrony, D.M., Egli, D.B., 1991. Relationship of seed vigour to crop yield. A Rev. Crop Sci. 31, 816–822.

The importance of rice in Sri Lanka | Blue Lanka [WWW Document], 2018. URL https://www.bluelankatours.com/blog/the-importance-of-rice-in-sri-lanka (accessed 12.1.18).

Thiruchelvam, S., 2005. Efficiency of rice production and issues relating to cost of production in the districts of Anuradhapura and Polonnaruwa. J. Natl. Sci. Found. Sri Lanka 33, 247–256. https://doi.org/10.4038/jnsfsr.v33i4.2114

Vidanapathirana, U., 2003. The Future of Paddy Farming Its Challenges and Constraints. Econ. Rev. 24–28.

Weerakoon, W.M.W., Mutunayake, M.M.P., Bandara, C., Rao, A.N., Bhandari, D.C., Ladha, J.K., 2011. Direct-seeded rice culture in Sri Lanka: Lessons from farmers. F. Crop. Res. 121, 53–63. https://doi.org/10.1016/J.FCR.2010.11.009

Zhao, D.L., Atlin, G.N., Bastiaans, L., Spiertz, J.H.J., 2006. Cultivar weed-competitiveness in aerobic rice: Heritability, correlated traits, and the potential for indirect selection in weed-free environments. Crop Sci. 46, 372–380. https://doi.org/10.2135/cropsci2005.0192

These experiments were conducted at the Rice Research and Development Institute, Batalagoda situated in LCIZ (IL3) during 2018/19 Maha seasons.

These experiments were conducted at the Rice Research and

Development Institute, Batalagoda situated in LCIZ (IL3) during 2016 Yala and 2016/17 Maha seasons. Three experiments were designed (i) to identify varieties suitable for MT compared with CT, (ii) to find out optimum WRS and PHSN and (iii) to identify optimum PD and SA to obtain a vigorous growth and maximum yield in mechanically transplanted rice using Kubota walk-behind type (Model NSP-4W) rice transplanter. The machine has the adjustment for changing WRS, PHSN and the PD. However, row width (between rows) of the transplanter is fixed as 30 cm since it was originated in Japan and was worked out for Japonica varieties having around 90 days of vegetative period during the growing season

Wet broadcast seeding In many irrigated and more reliable rainfed areas, pre‐germinated seed is broadcast into 2‐5cm of standing water. Seeding rates vary from 80‐120kg/ha and 1 person can plant 1 ha/day. Standing water levels are normally allowed to recede after seeding and water not added until the seedlings are 1‐2 leaf stage. If the soil surface dries to quickly then flash flooding of the fields may be needed. For this system to work effectively, fields must be level and have good drainage system. Seedling rearrangement will be required within 15‐20days after establishment. Weeds will need to be controlled with 21 days after establishment especially if a pre‐emergent herbicide has not been applied. This can be a very effective system for crop establishment, if there is a shortage of labor at planting, weeds can be managed and water

Rice Production Manual