CHAPTER 1
INTRODUCTION

Rice is one of the important food crops of the world providing major source of food for more than half of the human population. Rice is grown in 114 countries across the world on an area of about 161.42 million hectares with annual production of 678.68 million tonnes with a productivity of 4200 kg per hectare (FAOSTAT, 2010). More than 90 per cent of the world's rice is produced and consumed in Asia where it is an integral part of culture and tradition. The slogan "Rice is life" is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural household.

Rice is the most important staple food crop of India grown over an area of 41.92 million hectares which is maximum among all rice growing countries, with annual production of about 89.09 million tonnes and productivity of 2125 kg per hectare. Rice is the major food crop of the Kerala also. It was cultivated in 0.35 million hectares with a production of 0.77 million tonnes in 1999-2000. During 2009-10, rice is grown in a gross area of 0.23 million hectare producing 0.60 million tonnes with a productivity of 2.557 tonnes per hectare (Anon., 2010).

The three main rice growing seasons in Kerala are respectively as, virippu, mundakan and puncha. Virippu (autumn) is the first crop season which starts in April-May and extends up to September-October. Mundakan season (winter) is the second crop season which starts in September-October and extends up to December-January while puncha (summer) is the third crop season which starts in December-January and extends up to March-April. Of the three seasons, mundakan season is the predominant paddy growing season in Kerala (Leenakumary, 2007).

Generally, rice is grown under wetland condition. It may be grown in direct seeded or in transplanted condition. The high yielding rice varieties had been growing in transplanted condition since its innovation. Studies at the International Rice Research Institute (IRRI) in Philippines confirmed that there is no yield difference between direct seeding and transplanting practices of rice production if the weed control and other intercultural operations are carried out properly (Mohammed and Ahmad, 1998).

Recently, the area under rice crop is decreasing year by year due to less profitability and many other reasons. Transplanting of rice seedlings in the traditional way is laborious, time consuming and causes drudgery. The non-availability of labourers for transplanting at appropriate time leads to late planting, which results in poor yields. In paddy cultivation, the planting methods have an impact on the growth and yield besides cost of cultivation and labour requirement.

Transplanting is the most common and expensive method for obtaining good economic yields, but in transplanted rice the major operations like nursery preparation and management, pulling out seedling, transporting and distribution of seedlings to main field and transplanting consumes 30 to 40 per cent of total cost of cultivation. To get maximum returns, the cost of cultivation has to be reduced by minimizing the labour dependency in transplanting. Mechanized transplanting is the only solution to reduce cost of cultivation especially when large areas are to be transplanted in short period.

Further, in manual transplanting usually less number of hills are planted per unit area than recommended to complete the planting quickly resulting in reduced plant population and thus decreased in yields. In such situation, farmers prefer direct seeding by using drum seeder which is helpful due to less labour and time requirement, low cost of cultivation due to skipping of nursery raising and transplanting, maintaining recommended plant population and also due to early crop maturity by 7 to 12 days (Subbaiah *et al*., 2002; Gill, 2008).

Broadcasting of sprouted seeds in puddled fields is the usual practice followed by the farmers in the major rice growing areas of the state. The seed rate used for this method is much higher than the recommended. This generally affects the growth of plants and results reduced yields. Further, the weeding equipments cannot be operated in broadcasted fields.

Direct seeders can be used for controlled seeding in row with fixed spacing, which can rectify the major drawbacks of broadcasting. It is preferable, as it ensures an adequate crop stand and facilitates easy weeding and intercultural operations. The operation is simple and still people are reluctant to its use due to the unawareness.

Existing literature suggests that ergonomic appropriations can enhance production quality. Ergonomic evaluation of the farm implement can provide a rational basis for recommendation of methods and improvement in equipment design for more output and safety. Ergonomics is the scientific study of the relationship between man and his working environment, which includes ambient condition, tools and material, methods and organization of work. However, many of these cases are usually qualitative and subjective reports gained from field research. The evidence provided for the relationship between ergonomics and performance is usually inadequate and at many times it is contradictory. However there is a paucity of studies showing the direct relationship between ergonomic applications and performance outcomes such as productivity and quality.

The performance of direct paddy seeder and rice transplanter depends not only on the equipment but also on the worker operating it. The man machine performance may be poor, if ergonomics aspects are not given due attention. Due to the adoption of improper posture during work and heavy demand on workers biological systems, the equipment operation may cause clinical or anatomic disorders and will affect workers health. Proper attention into ergonomics aspects in design and operation will help in increasing the man equipment systems efficiency and also in safe guarding the operator`s health.

Human labour is the single costliest input in rice farming operations contributing to major part of the total cost of cultivation. Though ergonomic principles are considered at design level of many manually operated implements, the effects of its use in the field are not seriously studied for many implements. Hence there is an urgent need to study the ergonomic aspects to quantify the drudgery involved in the agricultural operations. This would greatly help the researchers to appropriately design simple and labour effective gadgets considering ergonomic requirements. Such designs of implements would not only minimize drudgery of the labour but also increase the productivity at reduced cost.

Ergonomic evaluation and performance analysis of direct seeder and mechanical transplanter are to be conducted to study the mechanical feasibility and cost economics.

Keeping in view of the above facts, the present investigation entitled "**Performance and Ergonomic evaluation of Direct Paddy Seeder and Mechanical Rice Transplanter in wet lands**" has been planned and was carried out at the instructional farm, KCAET, Tavanur during virippu (autumn season) (May-October), 2012 with the following objectives:

1. To study the machine parameters of rice transplanter.
2. To evaluate the performance of direct paddy seeder and a mechanical rice transplanter in field conditions.
3. To conduct the ergonomic evaluation of the direct paddy seeder and a mechanical transplanter for wet land rice.
4. To measure physiological response of male and female workers by using direct seeder and mechanical transplanter.

CHAPTER 2
REVIEW OF LITERATURE

A brief review of research work done in the field of lowland rice cultivation, transplanting and broadcasting methods of rice sowing, use of mechanical transplanter for rice etc. are included in this chapter. The importance of ergonomic evaluation of agricultural machinery and studies conducted in different types of ergonomic evaluation proceedings are also briefly narrated.

2.1 Wet or Lowland Cultivation

For centuries, lowland rice (wetland rice) cultivation has been practiced in submerged soils in Asia. Historically, wetland rice cultivation in Asia has been targeted at lands that are flooded or are prone to flooding during the wet/monsoon season. Wetland rice is able to take advantage of the benefits associated with flooding of the soils.

The major two practices in wet land cultivation are:

1. Transplanting in puddled fields
2. Broadcasting sprouted seeds in puddled fields

In these methods, the land is ploughed thoroughly and puddled with 3-5 cm of standing water in the field. The optimum depth of puddling is found to be around 10 cm in the clay and clay-loam types of soils. The primary objective is to obtain a soft seedbed for the seedlings to establish themselves faster, to minimize the leaching losses of nutrients and thereby increase the availability of plant nutrients by achieving a reduced soil condition which facilitates a better availability of nutrient elements, to incorporate the weeds and stubble into the soil and to minimize the weed problem. Puddling can be done mechanically with ploughs, power tillers or tractors with matching implements, depending upon their availability and soil conditions. The land is leveled after puddling to facilitate a uniform distribution of water and fertilizers.

Recent work in Philippines showed that there is, in fact little difference in yield between broadcast and transplanted rice, but that direct sowing requires the use of non-lodging varieties and a much higher standard of management. Transplanting may be advisable as a control for weeds, to offset the effects of low seed viability, poor water supply and control and to facilitate weed control (Grist, 1986).

2.1.1 Transplanting

Many studies reveal that transplanting is beneficial to the plant and results in increased yields. But great care is required in preparation of the nursery. It must be admitted that transplanting offers difficulties, the chief of which is the necessity of hand labour, but where these difficulties can be overcome or circumvented by the use of mechanical transplanter. In India the increase in yield through transplanting, has been 15 to 30 per cent (Ramaiah, 1954).

Transplanting is the most common method in Asia`s irrigated rice growing areas (Datta, 1986). They reported that expansion of irrigated areas, early maturing, profuse tillering cultivars, selective herbicides and improved fertilizer management coupled with reduced cost of production had encouraged many farmers to switch from transplanting to wet seeding.

i. Manual transplanting

The most common method of transplanting is to place 3 to 4 seedlings in the puddled field by hand. For transplanting, healthy seedlings have to be raised in the seed bed. The wet or dry method for raising seedlings can be adopted, depending primarily on availability of water. Following are the steps in raising wet nursery. Plough and harrow the field two or three times until the soil is thoroughly puddled and leveled. Construct raised beds 5 to 10 cm height, 1 to 1.5 m width and of convenient length with drainage channels between the beds. The total seed bed area should be 1000 m^2 for each hectare of the field to be transplanted (Bhatia and Vinaya, 1993).

Treat the seeds by wet method. Drain and incubate in warm, moist place for sprouting. Never allow the seeds to dry up. Moisten them occasionally. Sow germinating seeds on the third day.

The dry method is practiced in areas where sufficient water is not available and when time of planting is uncertain. The method involves through ploughing to incorporate the weed and straw into the soil. Apply compost or cattle manure at the rate of 1 kg m^{-2} of nursery bed. Sow seeds evenly over the bed and cover with fine sand. Water -the nursery as and when required depending upon the receipt of rains.

Seedlings are ready to be pulled out when they are in the 4-5 leaf stage; about 18 days after sowing for short duration varieties and 20 to 25 days after sowing for medium duration varieties. Irrigate seed bed about a day before pulling out the seedlings to soften the soil and to facilitate washing of roots. Pull out one or few seedlings at a time to reduce damage. Wash-off mud and soil from the roots carefully and group seedlings into bundles of convenient size for transplanting.

Before transplanting the seedlings, manuring and fertilizing are necessary. Transplant the seedlings at a depth of 3-4 cm, by hand (Anon, 1978). Investigations proved that the transplanting of paddy has a series of advantages over other methods. But manual transplanting requires considerable labour and is drudgerious. In many areas the manual transplanting is done not in a row which in turn creates greater problems. This method is painful to the labourers as there is bending position throughout the time of transplanting. Besides, approximately 30 % of the total labour requirement for rice production is accounted for transplanting and often results in labour scarcity during the peak season. Transplanting in rows of one hectare area normally requires 30 man days.

ii. Mechanical transplanting

Timeliness of transplanting is considered as very essential for various yields and there has been an increase in realization among rice growing countries to design and develop transplanters capable of performing precise and timely transplanting of rice seedlings at an acceptable cost (Kurup and Datt, 1981).

Singh *et al*. (1985) reported that transplanting takes about 250-300 man h ha^{-1} which is roughly 25 per cent of the total labour requirement of the crop. Further, due to rapid industrialization and migration to urban areas, the availability of labour became very scarce and with hike in the wages of labour, manual transplanting found costly leading to reduced profits to farmers. Under such circumstances a less expensive and labour saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi *et al*., 2004). The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity.

Some transplanting machines have mechanical transplanting devices that are hand fed but automatically place the seedlings. This arrangement allows the operators to work in more comfortable positions and tends to give more uniform placement. The device must be carefully designed to ensure that the plants will not be damaged and to preclude any possibility of injury to the operator (Kepner *et al*., 1987).

Transplanters are used for planting rice seedling in the puddle soil. The depth of pounded water in the field should not exceed 30 mm and uniform water depth is to be maintained all over the field.

Missing hill mostly depends upon the seedling density and its uniformity in the mat (Mufti and Khan, 1995). Higher missing of hills in their study was due to non-uniformity of seedling distribution in the mat. Besides that, silty clay loam soil of the seedling mat being sticky in nature might have caused problem in sliding of mat on the tray resulting in more missing of hills. Missing hill was found more than the allowable limit of 5%. Maintaining proper density of seedlings and uniformity in the mat is important.

Miller *et al*. (1991) observed that panicles per square meter were the most important component of yield and accounted for 89% of the varieties in yield. Data showed that plant density did not significantly affect the number of panicle bearing tillers.

Garg (1999) suggested that transplanting should not be done either on too soft and or on hard soil. He further reported that float sinkage less than 1 cm signified hard field condition which might pose problem in penetration of transplanting fingers into puddled soil. Assuming that float sinkage greater than 2 cm is indicative of soft soil, therefore, transplanting may be done at a float sinkage in between 1 to 2 cm.

Chiu and Fon (2001) developed an automatic tray loading/unloading machine for rice seedlings, riding on the transport gantry. The machine can orderly/continuously lays down the seeded trays via conveyors, on the nursery field for the field acclimatization and also pick up the trays with the mature seedling to the loading conveyor in sequence when the seedlings are ready for transplanting.

2.1.2 Broadcasting

Direct seeding under puddled soil enhanced the crop establishment, vegetative growth and reduced crop duration (Garcia *et al*., 1994).

Counce (1987) suggested that population density ranging from 159 to 304 plants per m^2 could produce maximum yield under a dry seeded and flooded rice production systems. The seeding rates from 50 to 168 kg ha^{-1} were necessary for obtaining maximum yields under direct seeded cultures depending upon planting dates, spacing between hills and rows, panicles per m^2.

Tajjudin *et al*. (1994) developed and evaluated a low land direct paddy seeder. The test result revealed that the paddy seeder could seed 104 kg ha^{-1} seed rate for 28 bored opening and 138 kg ha^{-1} for 40 bored opening. The seed germination tests conducted with the seeds showed that germination of paddy seeds was not affected by continuous rotation of seed drum. Field test showed that effective field capacity of the seeder was 0.12 ha h^{-1} with 63 % field efficiency. Cost of seeding by the seeder was ` 585 per ha as compared to ` 2060 per ha for manual transplanting.

Mohammed and Ahmad (1998) conducted an experiment to improve the performance of the drum type seeder developed by the IRRI for lowland paddy. The machine was evaluated and compared with the conventional hand seeding method. The effective field capacity of machine seeding ranged between 0.12 to 0.15 ha h^{-1} and that of hand broadcasting was 0.22 ha h^{-1}. The partial budget analysis revealed that by using drum type seeder and a rotary type seeder and a rotary type weeder, a farmer could earn a net benefit of US$ 55.06 per hectare compared to hand seedling followed by hand weeding. A farmer can save about US$ 56.00 per hectare by using BRRI modified drum seeder followed by a rotary weeder compared with hand seeding followed by hand weeding.

Subbaiah *et al*. (2002), Sharma *et al*. (2004), Gill (2008) and Gangwar *et al*. (2008) reported the higher grain yield in broadcasting might be due to avoidance of root injury and transplanting shock, quicker tiller initiation leading to longer tillering period. This impact has made it possible to record more number of tillers/m^2 with heavier panicles, which might have contributed to higher grain yield with the direct seeding method. They also reported that the higher net returns under direct seeded rice.

Gangwar *et al*. (2008) stated that the area of direct seeded rice in India is 7.2 mha. Thus, the direct seeded rice occupies 26 per cent of the total rice area in south Asia. Productivity of direct seeded rice often reported to be comparable with conventional transplanting method.

Manjunatha *et al*. (2009) explained the case of drum seeding. A modified drum seeder (IRRI model) was used. It was an eight row seeder spaced at 20 cm row spacing and required 9 kg of draft to operate the seeder. The drum was mounted on two wheels which were placed at both ends. Pre-germinated seeds (Soaking for 24 hours in water followed by incubation for 36-48 hours) of paddy were filled in the drums and the drum seeder was manually dragged on the field after draining the water to saturation. The mean grain yield in broadcasting method was 65.6 q ha^{-1} as compared to 56.59 q ha^{-1} in the case of transplanting and 61.88 q ha^{-1} in the case of drum seeding, registering 13.9 and 5.7 per cent increased grain yield over transplanting and drum seeding, respectively.

2.1.3 Direct seeding

Pradhan (1969) had demonstrated the successful adoption of direct seeding in lines in puddle rice fields using a seeder. This practice could replace transplanting without any attendant reduction in yield but with reduced cost. Row sown rice showed rapid establishment and greater vegetative growth due to absence of transplantation shock. Sowing of pre-germinated paddy seeds as an alternative to transplanting has gained acceptance over the years.

Shekhar and Singh (1991) stated that direct seeding of sprouted seed under puddle condition resulted in significant improvement in yield attributes. Borlagdan *et al*. (1993) reported the direct seeding requires much less labour and the yield comparable with transplanting can be achieved if the basic problems in direct seeding technique could be overcome.

In a direct-seeded system, seed rice is submerged in water for approximately 12 hrs and allowed to drain for 12 hrs to initiate the germination process. Direct Paddy Seeder is used for sowing of germinated paddy seed directly in wetland field. It is a manually pulled implement. Labour cost is reduced, uniformity in seed sowing and plant population, continuous drilling of seeds is eliminated, reduction in seed rate and thinning cost, crop matures 7-10 days earlier than the transplanted paddy, light in weight and easy to handle.

Direct seeding method is practiced in those areas where water is available for puddling. Transplanting, however, gives significantly higher yields than this method. Therefore, the farmers are advised to adopt transplanting method where water is available. Direct seeding of rice is a potential alternate, which, is a successful method in various rice growing countries of the world. The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity.

Wet seeded rice producing similar or higher yield than transplanted rice is well documented (Majid and Ahmad, 1996). Plant density exerts a strong influence on rice growth and grain yield, because of its competitive effect both on the vegetative and reproductive development. Hu *et al*. (2000) observed that grain yield increases linearly with plant density until some competitive effects become apparent. Feng *et al*. (2000) obtained a highest number of effective panicles with highest plant density.

2.2 Ergonomic evaluation

Gite and Singh (1997) stressed the importance of ergonomics in agricultural and allied activities in India. They summarized the research work carried out in the country in this field. Anthropometric data, muscular strength, maximal aerobic capacity, physiology of work etc were detailed in their study. A comprehensive review of the research work carried out on the following ergonomic aspects in briefly reported here in the following sub titles.

i. Selection of subjects
ii. Calibration of subjects
iii. Maximum aerobic capacity (VO_2 max)
iv. Overall discomfort rate (ODR)
v. Body Part Discomfort Score (BPDS)

2.2.1 Selection of subject

Selection of subjects plays an important role in conducting the ergonomic investigations. The subject should be medically and physically fit to undergo trials.

Astrand *et al*. (1965) stated that maximal oxygen uptake, heart rate, stroke volume, pulmonary ventilation and muscle strength decrease significantly with old age. The maximal aerobic power reaches a peak at the age of 18-20 years followed by a gradual decline.

The maximum force a muscle or groups of muscle capable depends upon age. The peak muscle strength for both man and women is reached between the ages of 25 and 35 years. Older workers aged between 50 and 60 can produce only about 75-85 per cent of muscular strength (Grandjean, 1982). Rodahl (1989) reported that maximum heart rate declines with age.

2.2.2 Calibration of subjects

To evaluate the physiological workload using heart rate, the relationship between heart rate and oxygen consumption rate must be determined for each subject. Both variables have to be measured in the laboratory at a number of sub maximal loads. This process is called calibration of subjects. With linear relationship of the heart rate and the oxygen consumption, the heart rate during the field trials can be predicted from the calibration charts (Bridger, 1995). Since it is difficult to measure the oxygen consumed by the subjects while performing various types of tasks, the subjects are calibrated in the laboratory.

Curteon (1947) reported that basal metabolic rate, heart beat rate and oxygen consumption rate are the pertinent parameters for assessing the human energy required for performing various types of operation.

Davies and Harris (1964) reported that the heart beat rate increases rapidly in the beginning of an exercise and reaches steady state by the end of sixth minute. At the start of the exercise there is a rapid rise in pulse rate and the maximum pulse rate is achieved within 5 seconds.

Clarke and Clarke (1965) reported that one of the most widely used techniques for exercised physiology research is treadmill in which specification may vary, but in general two variables that should be considered are speed and inclination.

Astrand and Rodhal (1977) pointed out that there is a linear relationship between heart rate and oxygen consumption in general. The heart rate under standardized conditions may be used as an index of oxygen uptake for a given task.

Astrand and Rodhal (1977) also stated that treadmill gives more effective results as compare to bicycle ergometer in calibration of the subjects. In bicycle ergometer, the subjects should be sitting almost vertically over the pedals. The seat should be high enough so that leg gets stretched full when the pedal is in the lower most position. Also they found that subject can continue to work at a reduced rate in almost all types of ergo meter. However in the treadmill subject was forced to follow the speed of the belt or jump off.

Brockway (1978) stated that the heart beat rate predicts the energy expenditure. Durnin (1978) correlated the heart beat rate and oxygen consumption by indirect calorimeter and indicated possibility of extrapolating the energy expenditure from the stabilized heart beat rate.

Karunanithi (1997), in his study of ergonomic evaluation of rice farming implements, found that the basal metabolic rate of the subjects varied in the range of 1450 to 1750 kcal per day.

Kroemer *et al*. (1997) stated that heart rate and oxygen consumption have a linear relationship. They found that the relationship may change within one person with training and it differs from individual to another. They inferred that heart rate measurements could be substituted for measurement of metabolic processes, particularly for oxygen consumption, since it could be performed easily.

2.2.3 Maximum aerobic capacity (VO_2 max)

The term VO_2 max represents an individual's capacity to utilize oxygen (aerobic capacity). It states that a point is reached where increase in work rate is no longer accompanied by increase in oxygen uptake and the individual as assumed to have reached her or his maximum level of oxygen uptake. Shortly after a person reaches a work rate, which exceeds his or her VO_2 max, the performance will decline dramatically (Bridger, 1995).

Rodahl (1989) reported that the maximal oxygen uptake is the highest oxygen uptake attainable in the subject in question, i.e. further increase in work load will not result in an increase in oxygen uptake.

2.2.4 Overall discomfort rating (ODR)

Borg (1962) developed a "category scale" for the rating of perceived excretion (RPE). The scale ranges from 6 to 20 with every second number anchored by verbal expressions. The scale ranges from 6 to 20 (to match heart rates from 60 to 200 beats min^{-1}), with every second number anchored by verbal expressions.

In 1970s, Borg developed a 15-point graded category scale to increase the linearity between the ratings and the workload was developed in 1970. Using this scale, ratings of perceived exertion values were shown to be approximately one-tenth of heart rate values for healthy, middle-aged men performing moderate to heavy exercise.

Gite *et al*. (1993) while conducting ergonomic evaluation of manual weeders, found that the postural discomfort (overall discomfort rating) varied from 3.0 to 5.1 on 8-point scale (0 - no discomfort, 8 - extreme discomfort) for a 15-min operation of each weeder.

Vidhu (2001) used the Borg-RPE 15 point scale and reported that the overall discomfort was maximum (16.13) for the conoweeder followed by seeding with direct paddy seeder (14.70), harvesting with self-propelled paddy harvester (14.60) and transplanting with manually operated paddy transplanter (14.37) using 15-point overall discomfort rating scale.

2.2.5 Body part discomfort score (BPDS)

Agricultural ergonomics has been gaining much importance in recent years. Evaluation of developed machines in ergonomic point of view is of utmost importance for attaining safety and comfort of the operator.

Astrand and Rodahl (1970) found that during continuous work lasting for at least 5 to 6 minutes, oxygen uptake equals oxygen demand and during the last 2 to 3 minutes of the activity, pulmonary ventilation, heart rate and other cardiovascular parameters were constant. They also reported same heart rates at a given sub maximal workload in old and young.

Reinberg *et al*. (1970) reported that the peak of muscle strength for both men and women is reached between the ages of 25 to 35 years old. Older workers between 50 and 60 years can produce only about 75 to 80 per cent of muscular strength compared to their younger days.

Corlett and Bishop (1976) used body mapping for assessment of postural discomfort at work. In this method, the perceived discomfort is referred to a part of the body. The subject's body is divided into 27 regions and the subject is asked to indicate the regions which are most painful, the subject is asked to mention all body parts. The subject is also asked to assess total discomfort from the worst on a particular body part, using a five or seven point scale. The scales are graded from "no discomfort" to "maximal discomfort".

Nag and Dutta (1980), Anonymous (2008) and Nag and Nag (2004) reported from different studies that pedal thresher have been limited to only assessment of change in heart rate and oxygen consumption rate. The physiological cost involved in threshing has been expressed in term of energy expenditure rate. All these studies have been conducted using a single operator whereas pedal threshing using two operators has not been explored.

Varghese *et al*. (1989) studied anthropometric parameters of female workers of different ages to assess the work methods and postural demands during work performance to enhance the operability, safety, convenience and comfort while performing domestic and occupational tasks.

Lusted *et al*. (1994) developed a body area chart discomfort checklist. It was used to rate the discomfort under dynamic condition to identify body area experiencing discomfort. Two discomfort checklists are to fill out, one at the start of the test and the second after a long period in the seat. The ratings are then compared to estimate the level of discomfort.

Agarwal *et al*. (2004) studied the effect of linkages of ergonomical performance of agricultural workers of Meghalaya in pedal paddy thresher operation. The threshers recorded 2 per cent of all the agricultural injuries due to inattentiveness, wearing of loose garments, overwork and physical incapability to mention few indicated.

Murali *et al*. (2007) found that the working heart rate was significantly higher than resting heart rate of the selected household and farm activities. He showed that VO_2 max of the selected women was ranging from 16.1 to 64.8 *ml* min^{-1} with a mean value of 39.89 *ml* min^{-1} and half of the respondents (50%) had very good physical fitness in the range of 41-45 *ml* min^{-1}. The working heart rate was significantly higher than resting heart rate of the selected household and farm activities.

Dewangan (2007) explained in ergonomic evaluation of paddy drum seeder. Relationship between heart rate and oxygen uptake was determined in the controlled laboratory condition. The body parts discomfort score were vary from 0 to 2.11 (Borg CR-10 scale) among the female and male agricultural workers.

Satapathy *et al*. (2008) studied ergonomical evaluation of pre-germinated paddy seeder with fifteen male subjects in the age group of 18–45 years. The mean value of WHR was recorded to be 135.7 beats min^{-1} and 144.6 beats min^{-1} with 4 row and 6 row seeders and OCR was noticed to be 0.95 and 1.06 $l\ min^{-1}$ for 4 row and 6 row paddy seeders respectively.

2.2.6 Physiological parameters and energy expenditure

Gross *et al*. (1973) feels comfort and discomfort results from the use of muscles and skeleton; posture as well as body movements. Comfort is often but not always coordinated with the amount of energy expended. That is less energy expenditure with greater comfort, the more with discomfort.

Grandjean (1973) observed extensive use of heart rate as a measure to know the extent of stress particularly under static conditions. According to him, heart rate within certain limits rises in direct proportion to the energy expenditure.

CHAPTER 3
MATERIALS AND METHODS

In this chapter the details of climatic conditions, materials used, selection of subjects for ergonomic evaluation of direct paddy seeder and mechanical transplanter and the procedure adopted for calibration of the selected subjects are explained. The details of computation of the assessment of performance indices such as seed rate, plant population, seedling distribution, missing hills, theoretical field capacity, speed of operation, effective field capacity, field efficiency, fuel consumption, grain yield, straw yield and ergonomic parameters like overall discomfort rating (ODR) and body part discomfort score (BPDS), overall safety rating (OSR) and overall ease of operation rating (OER) for the operation of the selected equipments are detailed.

3.1 Experimental site

The experimental field was located in the paddy field of the instructional farm of KCAET, Tavanur. The experimental field was typical wetlands of the region. It is situated at 10º 52' 30" North latitude and 76º East longitude. Agro climatically, the area comes in the border lines of northern, central and kole zones. The area receives the rainfall mainly from South West monsoon and a certain extent from northeast monsoon. The surface soil is sandy loam in texture comprising of 10% gravel, 65% sand, 12.5% silt and 12.5% clay.

3.2 Experimental Design and Treatments

Two plots of 755 m^2 and 545 m^2 were selected for the study. These plots are further subdivided into 4 plots of 270 m^2 each for conducting experiments by mechanical transplanting and direct seeding by male and female respectively. The remaining area of 200 m^2 was kept for manual transplanting for comparison.

3.3 Cultural operation

Paddy variety used for the study is 'Jyothi', the second most popular rice variety of Kerala, released from Regional Agricultural Research Station, Pattambi. Different steps involved in the cultural practices like nursery raising, land preparation etc. are described below.

3.3.1 Nursery raising

The procedure followed for preparing the mat type nursery for mechanical transplanting and traditional nursery for manual transplanting is described below.

i. Mat nursery preparation

"Korean make" mat nursery raising machine was used to prepare nursery in trays which ensures uniform seed distribution. The machine consists of four boxes, one each for seed, water and two for soil. Two 0.3 kW electric motors are acts as prime mover. A tray conveyor is provided these boxes to pass one after the other. The tray conveying system is so arranged that the required quantity of materials can be delivered into the tray by adjusting the control levers of the boxes. Plate 3.1 shows the mat nursery raising machine used for the experiment.

The seeds were soaked in water for a period of 12 hours after removing chaff and spread it over a plane surface for providing aeration. Dry the soil collected from the field after removing unwanted materials like grass, seeds of weeds and stones by sieving. The soil was filled in the first and last boxes, water in second box and seeds in the third box of the tray nursery raising machine. A trial run with the empty tray was initially done to find out the required seed rate by adjusting the lever to control the discharge of seeds. After setting the lever in appropriate position, switch on the motor and place trays one after the other over the conveying unit. At first the tray will be filled with soil when it passes the first box and a roller that comes after the first box slightly press and level the soil. Water is sprayed over the soil from the second box and seeds were dropped from third box. Finally a thin layer of soil is

Plate 3.1 Mat nursery raising machine

Plate 3.2 Checking of seed rate

Plate 3.3 Nursery preparation using nursery raising machine

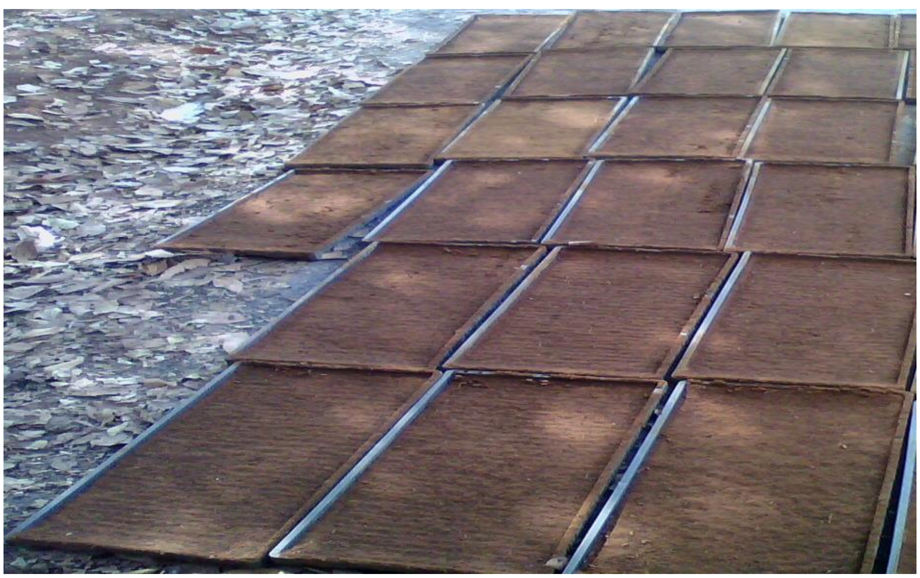


Plate 3.4 Filled trays by nursery raising machine

spread over the seed and the tray can be collected at the other end. The trays were arranged one over the other in a stack containing 10 trays. After 4-5 day, these trays were spread evenly in the field for growth of seedling. Small holes are provided in the tray to drain excess water.

ii. Traditional nursery

The field was well puddled and leveled by using tractor mounted rotavator. Raised beds were made as 2 to 3 cm height, 1 to 1.2 m wide and 10 m length with drainage channels between the beds. The total seed bed area is 1000 m^2 is for each hectare of the field to be transplanted. The seeds were treated by wet method. It was allowed to drain and incubate in warm and moist condition for sprouting. Sprouted seeds were evenly spread over the seed bed nursery.

3.3.2 Land Preparation

The experimental field was ploughed and leveled by using a tractor operated rotavator. The field was well nourished with organic manure. The field was irrigated for puddling purpose. After setting the soil, field was divided in to experimental plots as per layout plan.

For direct seeding, water was drained out for 24 hrs before sowing to form hard slurry pan of the puddle soil. At the time of sowing thin film of water was maintained in the puddle field.

For transplanting, water was drained out and allowed mud to settle for 2 days after final puddling. The subsurface soil layer was hard enough to support the transplanting machine.

3.3.3 Direct seeding

The direct (drum) seeder used was ‘Aiswarya’ 8 row paddy seeder. It is an improved seeder for sowing pre-germinated paddy seeds. It covers 8 rows of 20 cm row-to-row spacing at a time. Most component of the drum seeder made up of high density plastic materials. The shaft and handle are mild steel material. Hyperboloid

Plate 3.5 Traditional nursery

Plate 3.6 Ploughing by tractor mounted rotavator

Plate 3.7 Puddling and leveling

Plate 3.8 Puddled and leveled field ready for transplanting and direct seeding

shaped seed drum with 200 mm diameter and 9 numbers of seed metering holes of 10 mm diameter were there on both ends of the drum. Baffles are provided inside the seed drum between seed holes resulting in uniformity of seed rate throughout the operation. Each seed drum drops two rows of seed at a time. Four such drums are assembled to form 8 rows of seeds as shown in Plate 3.9. Wheels are provided at both ends. These wheels are made up of high density plastic material to reduce the weight of the equipment. One square shaft is used for mounting the four seed drums. A handle made up of mild steel pipe is provided for pulling the seeder along the field. The drum seeder used for the study is shown in Fig 3.1.

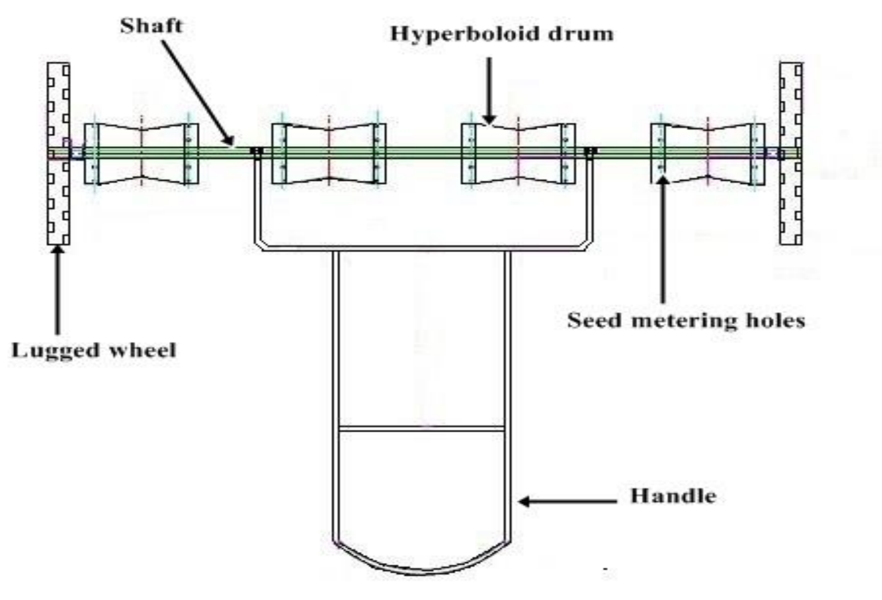


Fig 3.1 Schematic of Direct paddy seeder

i. **Experimental procedure**

Before field test, the drum seeder was calibrated in the laboratory to ensure seed rate and the workability of all the functional components.

When field was ready for direct seeding, the seeds were soaked in clean water. After 12 hrs of soaking, the water was drained out and seeds were kept in a gunny bag and tightly packed and kept for 24 hrs for sprouting. The degree of

Plate 3.9 Direct paddy seeder (Drum seeder)

Plate 3.10 Hyperboloid shaped seed drum

Plate 3.11 Direct seeding by male operator

Plate 3.12 Direct seeding by female operator

sprouting was observed very carefully so that the seeds can easily pass through the seeder holes. After 24 hrs, when the sprouting started the seeds were taken out and is filled in the seed drums to ⅔ of its capacity. The seeder was then pulled at a speed of about 1 km h^{-1} in the prepared field and the seeds were dispensed by the action of gravity. During operation the data on actual seeding time, turning time and loading times were noted. The effective field capacity and field efficiency were calculated and tabulated in Table 4.3. The experiment was conducted by using both male and female subjects.

3.3.4 Transplanting

i. Mechanical transplanting

The machine transplanting was done by using a 'Mahindra Model: PF 455S' four row rice transplanter (Plate 3.13). It is a walk behind type rice transplanter using mat type nursery and it transplants the seedling uniformly without damaging them. It has 30 cm row to row spacing and variable hill to hill spacing of 12.2/13.8/15.7 cm to a corresponding speed range of 1.22 to 2.66 km h^{-1}. The rice transplanter consists of prime mover, transmission, float, lugged wheels, seedling tray, seedling tray shifter, fork and cleaner. The planting depth and hill-to-hill spacing can be adjusted. Automatic depth control helps in maintaining uniform planting depth. The machine has safety clutch mechanism, which prevents break down of planting device from the impact against stones in the field. While operation, the machine is transported to the field and mat type nursery is loaded in the tray of the transplanter. The machine is put in transplanting mode and operated in the puddle field.

a. Experimental procedure

The mechanical rice transplanter was initially tested in the laboratory to check the working of all the functional components. The seedlings were taken out from the tray on the day of transplanting. Fifteen days old seedlings were transplanted in the experimental field by using mechanical transplanter. Transplanting was carried out by mechanical transplanter length wise in the prepared

Plate 3.13 Mahindra walk behind mechanical rice transplanter

Plate 3.14 Mat nursery seedlings ready for mechanical transplanting

Plate 3.15 Mechanical transplanting by male operator

Plate 3.16 Mechanical transplanting by female operator

field and at a minimum water level to avoid floating of seedlings. Observations on speed of operation, number of seedlings per hill, number of missed hills, time taken for turning, time taken for loading of seedling mat on to the transplanter, total time taken for transplanting, total area covered, width of coverage and quantity of fuel consumed for the operation were recorded. Using the above data the effective field capacity and field efficiency were computed for mechanical transplanter.

ii. Manual transplanting

Seedlings were pulled out at 4 to 5 leaf stage of the nursery i.e. about 18 days after sowing for short duration varieties. Seed bed was irrigated at least a day before pulling out the seedlings to soften the soil and to facilitate washing of roots. One or two seedlings pulled out at a time to reduce damage. Mud and soil is washed off from the roots carefully and grouped the seedlings into bundles of convenient size for transporting to main field.

The seedlings were then transplanted in the prepared field. Two to three seedlings per hill were transplanted at shallow depth at random spacing. Seedlings were handled carefully to ensure the fast revival and rapid growth after transplanting.

3.3.5 Other cultural practices

i. Fertilizer application

Nitrogen, phosphorous and potassium were applied at the rate of 70:35:35 kg ha^{-1}. Half of nitrogen and potassium and full dose of phosphorous were applied as basal dose. Remaining half doses of nitrogen and potassium were applied in two equal splits i.e. first at tillering and second at panicle initiation stage.

ii. Irrigation

A thin film of water was maintained at the time of transplanting. Normal irrigation was started after one week of transplanting. Depth of irrigation was increased to 2.5 cm progressively throughout various crop stages. Flooding of the puddle field was once in three days after sowing and drained out immediately. This

Plate 3.17 Traditional nursery ready for manual transplanting

Plate 3.18 Manual transplanting by female labour

practice continued for 12 days. Thereafter depending upon the height of the seedlings water was allowed to stand in the field.

iii. Intercultural operations

Since the period available for weeding is limited due to high soil moisture situation, efficient weeding methods are necessary. The cono weeder was used to remove weeds efficiently. It was easy to operate, and do not sink in the puddle soil. Cono weeder was run in same direction only, as direction in which the seeder was pulled.

iv. Harvesting and threshing

Harvesting was done at physiological maturity, judged visually when about 95 per cent grains were turned into golden colour. Kerala Agro Machinery Corporation Ltd (KAMCO) power reaper model KR-120 was used for harvesting. Area was harvested and kept separately for recording the yield. The product after harvesting was spread in the plots for sun drying.

Sun dried product tied in bundles, tagged and weighed for recording the biological yield per plot. The weighed material was threshed and the grain of individual plot was cleaned and grain yield per plot was recorded in kg. Then the yield of individual plot was calculated in kg ha^{-1}. Grain yield was subtracted from the biological yield to get straw yield per plot and converted it in to kg ha^{-1}.

3.4 Experimental methods

The methods and the experimental procedure followed to determine the different machine and crop parameters are explained for all practices under the following sub titles.

3.4.1 Calibration of direct seeder

The pre-germinated paddy seed was filled in the drums up to two - third capacity. The seeds dropped from the drums for N rotations of ground wheel were collected and weighed.

The seed rate can be calculated as given below:

i. Width of operation (m) = W = 1.8 m

ii. Length of a strip having nominal width W necessary to cover $^{1}/_{25}{}^{th}$ of an ha (m) = 10^4/W × 1/25 = 400/W

iii. Diameter of ground wheel (m) = D

iv. Number of revolution N required to cover the length of a strip L (rpm) = 400/ (ΠDW)

v. Weight of seeds from 4 drums in N rotation (kg) = M

vi. The seed rate in kg m^{-2} determined by measuring weight of seeds dropped in area (W×L). It is converted in to kg ha^{-1}.

3.4.2 Seedlings per hill

On 7th day after seeding and transplanting, the number of seedlings per hill was observed and recorded from three randomly selected places from each plot and the average were calculated.

3.4.3 Plant population and missing hills

The number of hills per m^2 of the plot was counted by placing a 1×1 m frame at 5 different locations in field. The number of hills and missing hills were counted and the average was calculated to find out number of hills per m^2 and percentage of missing hills.

3.4.4 Field capacity

i. Speed of operation

The speed of operation of the machine is observed in the field by noting down the time required to cover a fixed distance. The length of travel of the machine was marked using two poles at a distance of 20 m apart. The time required to cover this distance was noted using a stop watch.

Speed (km h^{-1}) = [distance (m) × 1000] / [time (sec) × 3600]

ii. Theoretical field capacity

Theoretical field capacity was calculated, based on the forwarded speed and the width of the equipment.

TFC (ha h^{-1}) = [Width of operation (m) × speed of operation (km h^{-1})] / 10

iii. Effective field capacity

The effective field capacity was calculated, based on area covered and actual time taken for covering the area including the time lost in turning and loading of seedlings. The effective field capacity was calculated by equation.

EFC (ha h^{-1}) = Area covered (ha) / Total time taken (h)

iv. Field efficiency

The field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage.

FE (η) = (EFC/TFC) × 100

3.4.5 Fuel consumption

Fuel consumption during the test run was found out by topping up at the starting point before operation. After operating for a fixed time, the machine was brought back to the initial marked position. The fuel tank was filled to same top up level by using a measuring cylinder. The volume of fuel used for refilling was noted.

Fuel consumption (l ha^{-1}) = volume of fuel consumed (l) / total area (ha)

3.4.6 Yield parameters

i. Grain yield

Harvesting was carried out by using KAMCO power reaper model KR-120. The crops were threshed, weighed and it is converted into kg ha^{-1}.

ii. Straw yield

Straw obtained after separating the grain yield was weighed and the value obtained was converted in to kg ha^{-1}.

3.5 Ergonomic Evaluation

Ergonomic evaluation of farm tools is necessary to improve the fit between the physical demands of the tools and the worker who perform the work. Ergonomical evaluation of the selected direct paddy seeder and mechanical rice transplanter was conducted for assessing their suitability with the selected subjects.

The evaluation was carried out by observing the following parameters.

i. Heart rate and Oxygen consumption rate (OCR)
ii. Overall discomfort rating (ODR)
iii. Body part discomfort score (BPDS)
iv. Overall safety rating (OSR)
v. Overall ease of operation rating (OER)

3.5.1 Selection of Subjects

According to Mc. Ardle *et al*. (2001), the subjects selected are in the age group of 18 to 45 years because they usually attain their highest strength level between 20 to 45 years. Selection of subjects plays a vital role in conducting the ergonomics studies. The subject should be medically fit to undergo the trials. They should not be suffering any major illness and handicaps and also they should be a true representative of the user population in operation of the selected implements. The following main criteria were used for the selection of subjects.

i. Age

The relation between the oxygen consumption and age of the workers was investigated and found that the maximum percentage of work could be expected during 20 to 30 years (Grandjean, 1982). The maximum strength or power can be expected from the age group of 25 to 35 years (Gite and Singh, 1997).

ii. Medical fitness

Fitness of an individual is a multivariate concept, although a distinction can be drawn between fitness and health (Kroemer, 1989). The performance of a job depends on the level of skill and the motivation of worker as well as on the fitness of the subject.

3.5.2 Heart rate monitor

The heart rate of the selected subjects was measured using Polar S810 computerized heart rate monitor. It is a compact portable instrument to monitor the heart rate. This can be used in the field directly where the telemetry system cannot be used. This polar pacer has the following four basic components (Plate 3.19).

i. Chest belt transmitter
ii. Elastic strap
iii. Receiver
iv. Interface

i. Chest belt transmitter (Polar coded)

It has two electrodes fixed in the grooved rectangular area on the underside of the belt transmitter, which picks up heart rate from the body of the subject and converts to electromagnetic signals. The electrodes are wetted with water before taking observations for better sensing.

ii. Elastic strap

This is to secure the belt transmitter as high under the pectoral muscles (breasts) as comfortable. The belt transmitter should fit comfortably and allow normal breathing. The transmitter with the elastic strap is secured on the subject along with the receiver.

iii. Receiver

This receiver unit was placed within one meter range and it was fitted in watchstrap. It is water resistant to 20-m water column. It receives the signals from the transmitter and displays it on screen and record the data in the memory with the help of battery CR 2025 fixed in it. It consists of buttons to operate the heart rate monitor. This has provision to set up high target zone and low target zone limits.

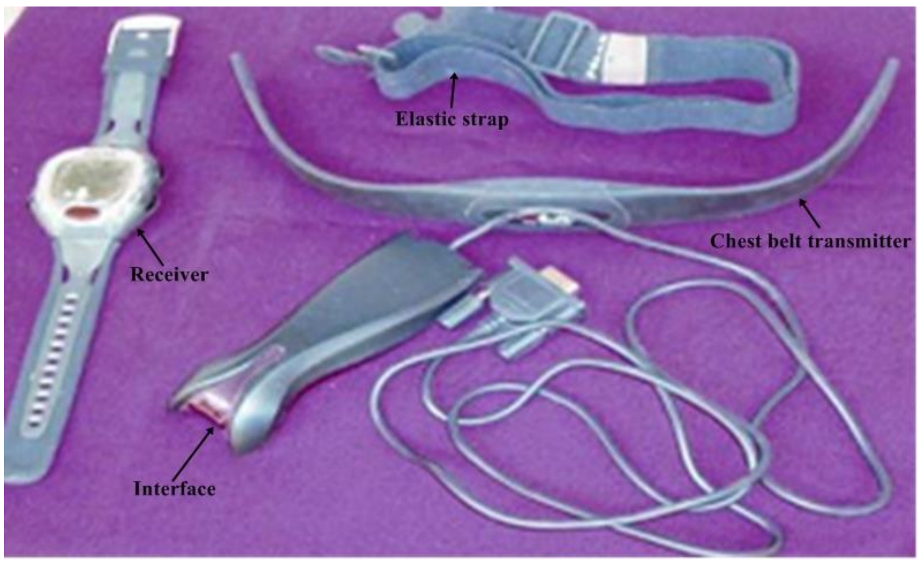


Plate 3.19 Polar S 810 computerized heart rate monitor

When the subject reaches that limit of heartbeat it will indicate through alarm, or visual alarm. Similarly the low heart rate target zone will be helpful in certain critical condition.

iv. Interface

This unit transmits the recorded heart rate values to the computer. The interface on its incorporation with the computer will transmit the recorded heart beat values of the subject to the computer and the heart rate values are displayed in graphical form representing time vs. heart rate, maximum, minimum and average heart rate values of the subject during the operation.

3.5.3 Heart rate and oxygen consumption rate

i. Heart rate

The heart rate (beats min^{-1}) is recorded by mounting heart rate monitor. In this experiment, Polar Sport Test Heart Rate Monitor (S-810 Model) was used to record the heart rate of the subjects while performing the experiment.

ii. Oxygen consumption

The term oxygen consumption means the amount of oxygen consumed by the whole body of subject per unit time, which is normally expressed as $l\ min^{-1}$.

Heart rate is a primary indicator of circulatory function and oxygen consumption representing the metabolic conversion-taking place in the body. It is a linear and reliable relationship. Heart rate response was more quickly to changes in work demands and hence indicates more readily quick changes in body function due to changes in work requirement (Kroemer *et al.*, 1997).

3.5.4 Energy consumption

The maximum heart rate during operation was used to calculate the mean value for both the selected equipments. The oxygen uptake (VO_2) and energy consumption of the subjects for both equipments were determined by using the equations in Table 3.1 as suggested by Phillip (2001).

Table 3.1 Relationship between heart rate, oxygen uptake and energy consumption

H/W ratio	VO_2 uptake (*l* min^{-1})	Energy consumption (kJ min^{-1})
Below 2.5	0.018 HR− 0.7765	0.2372 HR− 15.554
2.5-3.0	0.0102 HR− 0.5324	0.203 HR− 10.483
Above 3.0	0.0088 HR− 0.4952	0.1768 HR− 9.918

3.5.5 Overall discomfort rating (ODR)

The trials for discomfort rating for selected implements were carried out in same field condition. The subjects were allowed to take rest for a period of half an hour prior to test (Phadke *et al*., 1992). Overall discomfort rating (ODR) shall be measured on a 10-point visual analogue scale (0- no discomfort, 10-extreme discomfort) that is an adoption of a technique developed by Corlett and Bishop (1976). At the end of each trial, the subjects were asked to indicate their overall discomfort rating by putting '√' mark on the scale shown in Table 3.2.

Table 3.2 Overall discomfort rating (ODR)

No discomfort	Light discomfort		Moderate discomfort		More than moderate		Very uncomfortable		Extreme discomfort	
0	1	2	3	4	5	6	7	8	9	10

3.5.6 Body part discomfort score (BPDS)

BPDS is a subjective method for direct ascertainment of aware discomfort. A tool used for analysing workplace activities is the Body Part Discomfort Form. Such forms are based on the principle that the static loads (static work) involved in a given activity can be assessed by measuring the muscular pain experienced. Identifying the level and location of the pain permits a direct evaluation of the activities performed.

In the Corlett and Bishop (1976) technique, subject`s body is divided into 27 regions. Regions of body map for evaluating BPDS given in Fig 3.2. The subject was

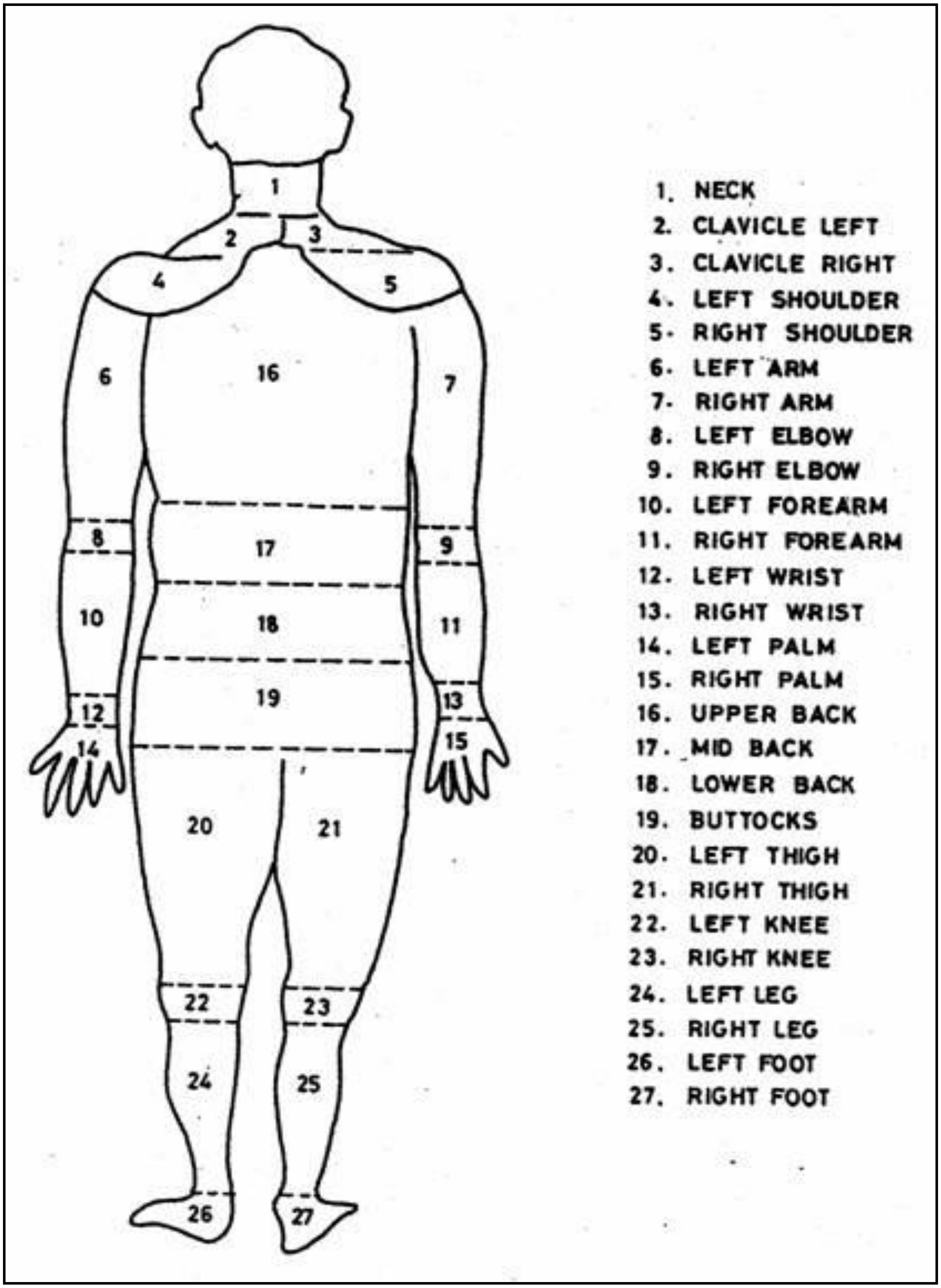


Fig. 3.2 Regions of Body Map for evaluating BPDS

asked to mention all body parts with discomfort, starting with worst, second worst and so on until all parts have been mentioned (Lusted *et al*., 1994). The subject was asked to write ‘1’ on the body part for max pain, ‘2’ for next max pain and so on. The number of different groups of body parts which are identified from extreme discomfort to no discomfort represented the number of intensity level of pain experienced.

The max numbers of intensity levels of pain experienced for the operation of the equipment were categorized. The rating will assigned to these categories in an arithmetic order as explained below viz., if the max number of intensity levels of pain experienced for the operation was 6 categories, first category (body parts experiencing max pain) rating was max 6 and for second category (body parts experiencing next max pain) rating was allotted as 5 and so on. For the sixth category (body parts experiencing least pain) rating was allotted as 1. The number of intensity levels of pain experienced by different subject might be varying.

For example, if one subject has experienced 4 categories, first category (body parts experiencing max pain) rating was allotted as 6 and for second category (body parts experiencing next max pain) rating was allotted as 4.5 and so on. For the fourth category (body parts experiencing least pain) rating was allotted as 1.5. The body part discomfort score of each subject will be the rating multiplied by the number of the body parts corresponding to each category. The total body parts score for a subject will be the sum of all individual scores of the body parts assigned by the subject.

3.5.7 Overall safety rating (OSR)

A 10 - point psychophysical rating scale (0 – completely secure and no fear, 10 – Totally insecure and extreme fear) was used for the assessment of safety rating, which is an adoption of Corlett and Bishop (1976) technique. A scale as shown in Table 3.3 was prepared having 0 to 10 digits marked on it equidistantly. At the ends of each trial subjects were asked to indicate their safety rating on the scale by using a pen. The overall safety ratings given by the subjects were found out and analyzed to interpret the results.

Table 3.3 Overall safety rating (OSR)

Completely secure and no fear	Secure and meager fear		Moderately secure and less fear		Slightly secure and moderate fear		Insecure and more fear		Totally insecure and extreme fear	
0	1	2	3	4	5	6	7	8	9	10

3.5.8 Overall ease of operation rating (OER)

A 10 - point psychophysical rating scale (0 – very easy, 10 – extremely difficult) was used for the assessment of ease of operation, which is an adoption of Corlett and Bishop (1976) technique. A scale as shown in Table 3.4 having 0 to 10 digits marked on it equidistantly was prepared. At the ends of each trial subjects were asked to indicate their ease of operation rating on the scale by using a pen.

Table 3.4 Overall ease of operation rating (OER)

very easy	Easy		Less difficulty		Difficult to operate		Very difficult		Extremely difficult	
0	1	2	3	4	5	6	7	8	9	10

CHAPTER 4
RESULTS AND DISCUSSION

This chapter deals with the results of the studies conducted with direct paddy seeder and walk behind type mechanical transplanter. The evaluations of all operations involve in both systems and were compared with manual transplanting system. The performances were evaluated based on seed rate, plant population, seedling distribution, missing hills, speed of operation, theoretical field capacity, effective field capacity, field efficiency, fuel consumption, grain and straw yield and the results are presented in Table 4.11, 4.12, 4.13, 4.14. The effects due to human factors like heart rate, oxygen consumption on the performance of the equipments were assessed and results are discussed. Overall discomfort rating (ODR), overall safety rating (OSR), overall ease of operation rating (OER) and body part discomfort score (BPDS) of selected male and female subjects during these operations were studied and the results are compiled.

4.1 Direct paddy seeder

Direct paddy seeder was evaluated with paddy variety Jyothi during last virippu (autumn season 2012). The quantity of the sprouted seeds used for an area of 540 m^2 was 2 kg. In direct seeding, 75 to 78 per cent time was actually required for seeding, 10 to 12 and 10 to 13 per cent time were lost in turning and loading operations respectively.

The distance between rows was observed as 20 cm and the distance between seeds dropped in a row was varied with the seeding rate. Since the diameter of drive wheel was 60 cm and the seed drum had 9 metering holes around its circumference, the theoretical distance between the hills along the row should be 20.9 cm. In the field operation the actual distance between hills was varied from 20.6 to 22.4 cm. The average spacing comes to 21.8 cm, which was slightly higher than the theoretical value. This difference might have been caused by the wheel slippage and irregular seed dropping due to bridging and moment of inertia of the seeds within the drum. The technical specification of direct paddy seeder is presented in Table 4.1.

Table 4.1 Specification of direct paddy seeder

Power Source	Manual
Row to row spacing	200 mm
Overall dimensions	2000 x 1500 x 640 mm
Shape of the seed drum	Hyperboloid
Number of rows	8
Diameter of the drum	200 mm
Diameter of the seed metering hole	10 mm
Number of seed metering hole	9
Weight of the unit	10 Kg.
Weight of one seed drum	600 grams
Type of ground wheel	Lugged wheel
Diameter of the ground wheel	600 mm
Operating speed / Walking speed	1 Km h^{-1}
Level of filling the seed drum	$^{2}/_{3}{}^{rd}$

4.2 Mechanical transplanter

The technical specification of the walk behind type mechanical transplanter used for the study is presented in Table 4.2.

The transplanter was evaluated in the field using seedlings prepared in nursery raising machine in seeding trays. In the field experiments, it was observed that the number of seedlings transplanted per hill was 3 to 4 and depth of planting was about 5 cm for mechanical transplanter. The performance of the mechanical transplanter was quite satisfactory and the labour requirement was 3 man days per hectare as against 33 man days per hectare in case of traditional transplanting. Thus saving of 30 man days of labour per hectare was obtained.

Table 4.2 Specification of mechanical rice transplanter

Make	Mahindra
Model	PF 455S
Type	Walk behind 2-wheel 3 float
Overall dimensions	
Length	2450 mm
Width	1480 mm
Height	840 mm
Weight	170 kg
Fuel tank capacity	3.2 lit
Engine	
Type	Air cooled 4-stroke petrol engine
Bore x Stroke	62mm x 43 mm
Rated Horse power	2.3HP @ rated rpm
Rated rpm	3600
Displacement	130 cc
Starting mechanism	Recoil Starter
Transmission	
No. of Speeds	2 Forward, 1 Reverse
Speed of operation	1.22 - 2.66 Km h^{-1}
Planting Mechanism	
Type of Seedling	Mat type
No. of Planting arms	4
Row spacing	30 cm (Standard)
Number of seedlings per hill	3 to 5
No. of hills per m^2	27 / 30 / 33
Hill spacing	15.7 / 13.8 / 12.2 cm

4.3 Performance of direct paddy seeder and mechanical transplanter

The results of the performance analysis of direct paddy seeder and mechanical transplanter in comparison with manual transplanting was consolidated and presented in Table 4.3.

Table 4.3 Performance analysis of direct paddy seeder and mechanical transplanter in comparison with traditional manual transplanting

Parameters	Direct seeding	Mechanical transplanting	Manual transplanting
Seed rate, kg ha^{-1}	37	55	72
No. of seedlings/hill	5-6	3-5	2-3
No. of hills/m^2	27	31	29
Missing hills, per cent	2.80	1.60	_
Row spacing, cm	20	30	_
Average hill spacing, cm	21.8	13.8	22.6
Working speed, km h^{-1}	1.02	1.33	0.21
TFC, ha h^{-1}	0.16	0.15	_
EFC, ha h^{-1}	0.11	0.12	0.02
Field efficiency, %	69	74	_
Fuel consumption, l ha^{-1}	_	3.7	_
Grain yield, kg ha^{-1}	2265	2652	2025
Straw yield, kg ha^{-1}	2885	3482	2508

4.3.1 Seed rate

The seed rate of direct paddy seeder was calculated as explained in section 3.4.1. The average seed rate obtained is 37 kg ha^{-1} for direct paddy seeder. It is very low as compared to the mechanical transplanting having 55 kg ha^{-1} by using nursery raising machine and manual transplanting with 72 kg ha^{-1}. It is seen that the seed rate obtained with direct paddy seeder was 48.6 % and 32.7 % lower than that of manual and mechanical transplanting respectively.

4.3.2 Seedlings per hill

The number of seedlings per hill was observed and recorded as explained in section 3.4.2. The number of seedlings per hill was 3 to 5 for mechanical transplanting and 2 to 3 for manual transplanting. It was observed that 5 to 6 seeds dropped per hill while operating the direct seeder at a speed of 1 km h^{-1}.

4.3.3 Plant population and missing hills

The number of hills per one square meter area and the percentage of missing hills were calculated as explained in section 3.4.3. It was observed that there were 27 hills per square meter in direct seeding. Whereas the number of hills per square meter was 31 and 29 for mechanical and manual transplanting respectively. The missing hills in direct seeder and mechanical transplanter were found to be 2.80 per cent and 1.60 per cent respectively but in case of manual transplanting method, with no missing hills.

4.3.4 Field capacity

i. Speed of operation

The speed of operation of the machine was calculated as explained in section 3.4.4.i. The speed of direct seeder in the field was found to be 1.02 km h^{-1}. The speed of mechanical transplanter in the field was 1.33 km h^{-1}.

ii. Theoretical field capacity

Theoretical field capacity was calculated as explained in section 3.4.4.ii. The TFC of direct seeder and mechanical transplanter was 0.16 ha h^{-1} and 0.15 ha h^{-1} respectively.

iii. Effective field capacity

Effective field capacity obtained for direct seeder and mechanical transplanter was 0.11 ha h^{-1} and 0.12 ha h^{-1} respectively. Whereas the same was found to be 0.02 ha h^{-1} with manual transplanting.

iv. Field efficiency

The field efficiency calculated as explained in section 3.4.4.iv. It was found to be 69 per cent for direct seeder and 74 per cent for mechanical transplanter.

4.3.5 Fuel consumption

Fuel consumption of mechanical transplanter was fond to be 3.7 *l* ha^{-1}.

4.3.5 Yield parameters

i. Grain yield

The grain yield was measured as explained in section 3.4.6.i. The mean grain yield in mechanical transplanting method was higher 2652 kg ha^{-1} as compared to 2265 kg ha^{-1} for drum seeding and 2025 kg ha^{-1} for manual transplanting.

ii. Straw yield

The straw yield was the highest for mechanical transplanting method with 3482 kg ha^{-1} as compared to direct seeding with 2885 kg ha^{-1} and manual transplanting with 2508 kg ha^{-1}.

4.4 Ergonomic evaluation of the selected equipments

Ergonomic evaluation of the selected equipments viz. direct paddy seeder and mechanical transplanter were carried out with male and female subjects in terms of the following parameters as explained in section 3.5.

i. Heart rate and Oxygen consumption rate
ii. Energy consumption
iii. Overall discomfort ratings (ODR)
iv. Body part discomfort score (BPDS)
v. Overall safety rating (OSR)
vi. Overall ease of operation rating (OER)

4.4.1 Selection of subjects

One male and one female subject were selected for the investigation based on their age and medical fitness. The physiological characteristics of the subjects were presented in Table 4.4.

i. Age

Both subjects were equally trained persons in the operation of the selected direct paddy seeder and mechanical rice transplanter. The age of the selected male subject was 32 years and female subject was 29 years.

ii. Medical fitness

Detailed examinations were conducted to assess the medical fitness of the selected subjects as like physically fit, mentally fit and for critical injuries. They were also free from illness and any critical injuries during operations. The body mass index (BMI) was 20.56 kg m^{-2} and 22.76 kg m^{-2} in the range of 20.5–23.25 kg m^{-2} that indicated that both subjects were in normal health as per the classification given by Garrow (1987).

Table 4.4 Physiological Characteristics of the selected subjects

Physiological Characteristics	Male	Female
Age (yr)	32	29
Height(cm)	165	161
Weight (kg)	56	59
BMI (kg m^{-2})	20.56	22.76
H/W ratio	2.9	2.7

4.4.2 Heart rate (HR) and Oxygen consumption rate (OCR)

The heart rates of the selected subjects were measured using the computerized heart rate monitor and the corresponding values of oxygen consumption rate (VO_2) of the subjects were calculated as explained in section 3.5.3. The heart rate values (HR) recorded in the computerized heart rate monitor during the operation of the selected equipments were down loaded to the computer and the values for individual subjects for different operations were obtained and data is presented in Appendix III.

4.4.3 Energy consumption

The corresponding values of energy consumption of the subjects were calculated as explained in section 3.5.4 and is presented in Table 4.5. The subjects had H/W ratio in the range of 2.5-3.0. Oxygen uptake and energy consumption were found out directly using Table 3.1.

Table 4.5 Mean value of HR, oxygen consumption and energy consumption

Parameters	**Direct seeder**		**Mechanical transplanter**	
	Male	**Female**	**Male**	**Female**
Heart rate (beats min^{-1})	145.5	148.9	131.6	134.1
Oxygen consumption, (l min^{-1})	0.95	0.98	0.80	0.83
Energy cost (kJ min^{-1})	19.05	19.74	16.23	16.74

Table 4.6 Classification of Physiological Workload by Nag (1980)

Physiological Workload	**Heart rate (beats min^{-1})**	**Oxygen consumption (l min^{-1})**	**Energy Expenditure (kJ min^{-1})**
Very light	Up to 90	< 0.38	Up to 7.78
Light	91-105	0.38-0.54	7.78-10.83
Moderate	106-120	0.54-0.70	10.83-13.87
Heavy	121-135	0.70-0.84	13.87-16.92
Very heavy	136-150	0.84-1.00	16.92-19.97
Extremely heavy	>150	> 1.00	>19.97

The mean resting heart rate of the subjects was found to be in a range of 65 - 75 beats min^{-1}. The average working heart rate (HR work) of the subjects when operating direct seeder was 145.5 and 148.9 beats min^{-1} for male and female subjects respectively. The corresponding values with the mechanical transplanter was 131.6 and 134.1 beats min^{-1} for male and female respectively. The trend in the rise of HR

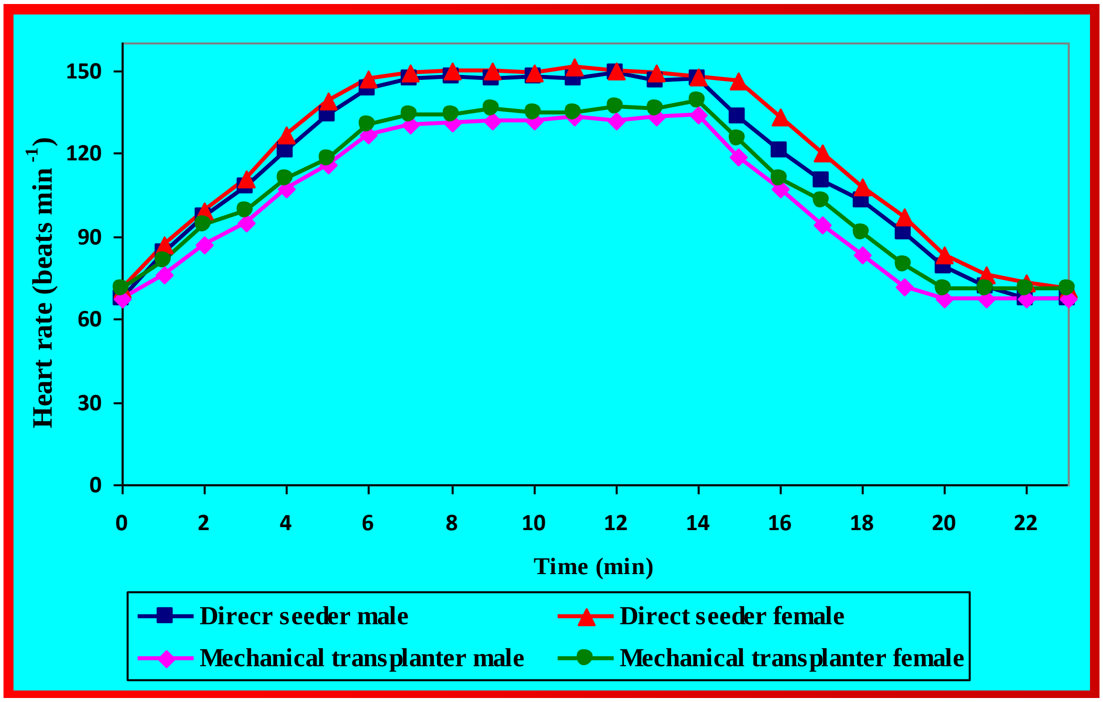


Fig 4.1 Mean heart rate and recovery pattern during the operation of selected equipments

work has been shown in fig 4.1. The HR work increased till six minutes of operation in all cases and stabilized thereafter. The HR recovered to its pre-work stage after 8 minutes of rest in case of direct seeder whereas it was 6 minutes in case of mechanical transplanter. This showed that a rest pause of 8 minutes could be given to the operator before restarting the job.

After 8 min of work, the heart rate of the subject stabilizes in the range of 121–135 beats min^{-1}, the work can be rated as heavy type of work and the heart rate of the subject stabilizes in the range of 135–150 beats min^{-1}, the work can be rated as very heavy type of work (Christiansen, 1953).

The OCR of male and female subjects, for 8 row direct seeder was found to be 0.95 l min^{-1} and 0.98 l min^{-1} respectively. But in case of 4-row mechanical rice transplanter, the OCR observed to be 0.80 and 0.83 l min^{-1} for male and female subjects respectively. Energy requirement of male and female subjects for direct seeder has found to be 19.05 kJ min^{-1} and 19.74 kJ min^{-1} respectively. But for mechanical transplanter it was 16.23 kJ min^{-1} and 16.74 kJ min^{-1} for male and female subjects respectively.

So as per Table 4.6 the operation with mechanical transplanter is graded as "heavy" and that for direct seeder it is graded as "very heavy". The energy demand required for manual transplanting is approximately 11.15 kJ min^{-1} and it is graded as "moderate". The energy expenditure for selected operations in paddy cultivation indicated that the energy cost of work for seeding with direct seeder is highest followed by transplanting with mechanical transplanter and manual transplanting.

4.4.4 Overall discomfort rating (ODR)

The overall discomfort scores of each male and female subject for the selected equipments were found out as explained in section 3.5.5. The ODR for the operation of selected equipments with both subjects are furnished in Table 4.7.

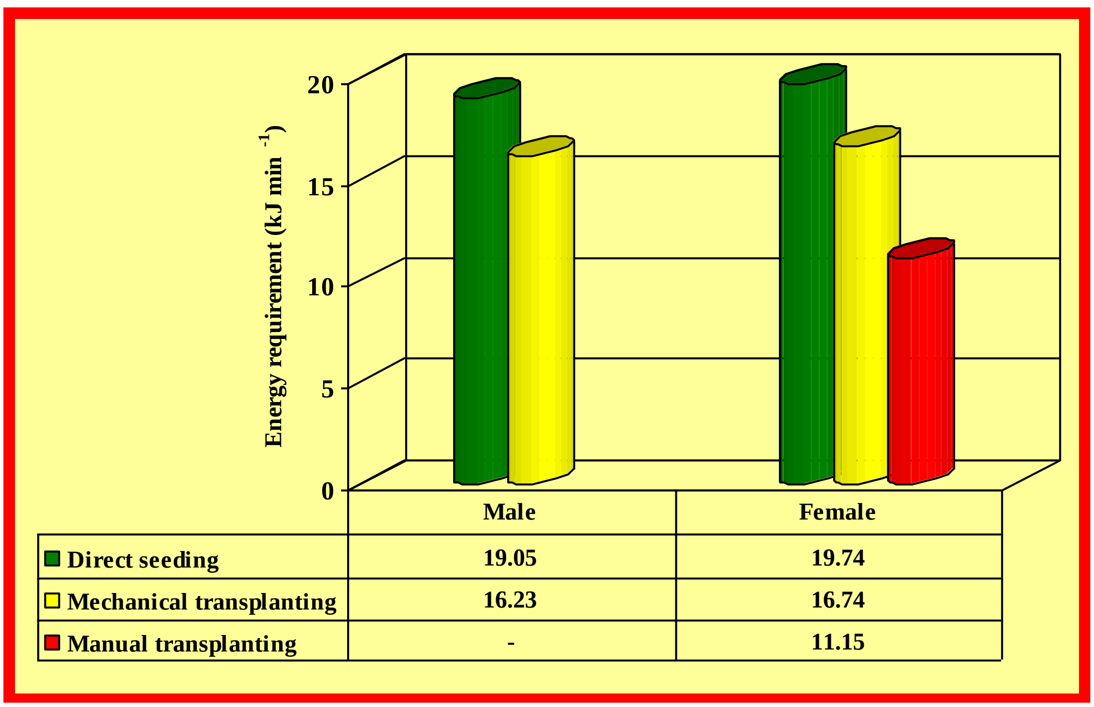


Fig 4.2 Energy requirement of different rice sowing method

Table 4.7 Overall Discomfort Rating for different operations

Operation	Subject	Rating	Scale
Direct seeding	Male	6.5	More than moderate
	Female	7.5	Very uncomfortable
Mechanical transplanting	Male	3.0	Moderate discomfort
	Female	3.5	Moderate discomfort

The values of overall discomfort rating of the male were observed to be 6.5 for direct seeder and 3.0 for mechanical transplanter respectively. The values of overall discomfort rating of the female were 7.5 for direct seeder and 3.5 for mechanical transplanter. It is observed that the overall discomfort experienced by the both subject was less for mechanical transplanter compared to direct paddy seeder. This is due to the support of prime mover in case of mechanical transplanter against pulling type direct paddy seeder. It is also understood that the 8 row direct paddy seeder is not suitable for female subjects based on ODR.

4.4.5 Body part discomfort score (BPDS)

The body part discomfort score for all the selected equipments were found out as explained in the section 3.5.6. The Body part discomfort score values assessed for both selected equipments are furnished in Appendix IV and the mean values of BPDS of the male and female subjects are furnished in Table 4.8.

The values of BPDS of the both male and female subjects were observed as 40.8 and 45.6 respectively for direct seeder and for mechanical transplanter the BPDS were 36 for both subjects. It is observed that the BPDS of male and female subjects were maximum for the direct seeder.

Table 4.8 Body part discomfort for direct seeding and mechanical transplanting

Operation	BPDS	Score	
		Male	**Female**
Direct seeding	Heavy pain in foots, forearms, knees and shoulders Moderate pain in thighs, legs and palms	40.8	45.6
Mechanical transplanting	Moderate pain in knees, legs, elbows and shoulders Less pain in palms and forearm	36	36

The heavy pain was experienced by the workers at foots, right shoulder, left shoulder, knees, forearms and moderate pain at thighs, legs and palms during direct seeding. The moderate pain was experienced by the workers at knees, legs, elbows, shoulders and less pain at palms and forearms for both the subjects during mechanical transplanting. This discomfort experienced by the subjects was mainly due to the alternate push-pull action associated with the operation coupled with the additional effort required to walk in the puddled paddy fields.

4.4.6 Overall safety rating (OSR)

The overall safety rating of male and female subjects for all the selected equipments were found out as explained in section 3.5.7. The OSR for the operation of selected equipments with both subjects are furnished in Table 4.9.

Table 4.9 Overall Safety Rating for different operations

Operation	Subject	Rating	Scale
Direct seeding	Male	0	Completely secure and no fear
	Female	0	Completely secure and no fear
Mechanical transplanting	Male	1.5	Secure and meager fear
	Female	1.5	Secure and meager fear

The values of OSR of male and female subjects for direct seeder were found to be same (zero-0). But for mechanical transplanter it was found to be 1.5 for both male and female subjects. From OSR it observed that the direct seeder is completely secure with no fear and mechanical transplanter is secure and meager fear.

4.4.7 Overall ease of operation rating (OER)

The overall ease of operation rating of male and female subjects for the selected equipments were found out as explained in section 3.5.8. The OER for the operation of selected equipments with both subjects are furnished in Table 4.10.

Table 4.10 Overall Ease of Operation Rating for different operations

Operation	Subject	Rating	Scale
Direct seeding	Male	6.0	Difficult to operate
	Female	7.5	Very difficult
Mechanical transplanting	Male	3.5	Less difficulty
	Female	5.0	Difficult to operate

The values of OER for the male subject were observed to be 6.0 and 3.5 for direct seeder and mechanical transplanter respectively. These values for female subject were observed to be 7.5 and 5.0 respectively for direct seeder and mechanical transplanter. OER values for direct seeding for male subjects comes under ‘difficult to operate’ scale range. This may be due to the pulling of 8 row seeder in the puddled field is little bit difficult. But for female subject the 8 row direct seeder is ‘very difficult’ to operate. So for female subject it is better to use direct seeder with lesser number of rows. For both subjects, walk behind mechanical transplanter is comparatively easier than pulling direct seeder.

4.5 Comparison of direct paddy seeder and mechanical transplanter

The performance data of the 8 row direct seeder and walk behind type mechanical transplanter on the basis of seed parameters, field parameters, machine performance parameters, yield parameters and ergonomic parameters are presented in Table 4.11 to Table 4.15.

Table 4.11 Seed parameters of different rice cultivation method

Parameters	Direct seeding		Mechanical transplanting		Manual transplanting
	Male	Female	Male	Female	
Variety of rice	Jyothi	Jyothi	Jyothi	Jyothi	Jyothi
Type of nursery/seed	Pre-germinated seeds	Pre-germinated seeds	Mat	Mat	Traditional
Date of nursery	_	_	02/07/12	02/07/12	29/06/12
Date of planting	16/07/12	16/07/12	17/07/12	17/07/12	24/07/12
Quantity of seed, kg	1	1	1.5	1.5	1.45
Seed rate, kg ha^{-1}	37	37	55	55	72
Nursery duration, days	_	_	15	15	25
Seedling height, cm	_	_	13-16	13-16	21-23

From the Table 4.11 it is revealed that the seed rate was found to be the least for direct seeding followed by mechanical transplanter and manual transplanting.

Table 4.12 Field parameters of different rice cultivation method

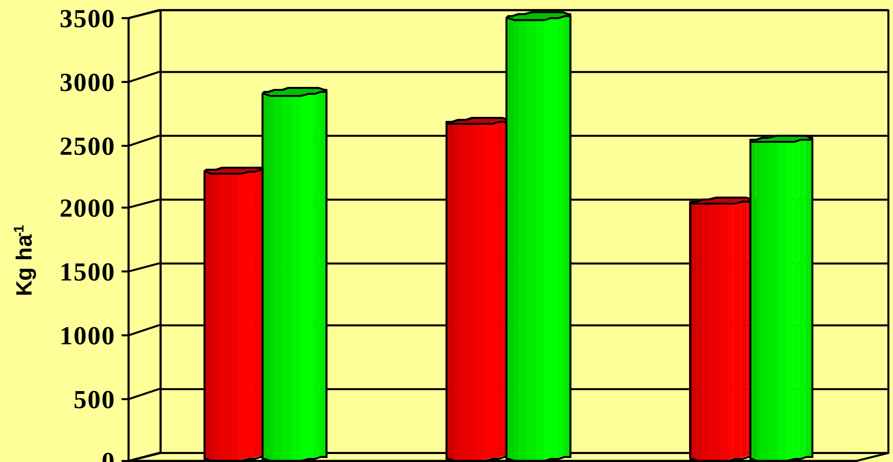
Parameters	Direct seeding		Mechanical transplanting		Manual transplanting
	Male	Female	Male	Female	
Area of the field, m^2	270	270	270	270	200
Type of soil	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy Loam
Retention period after puddling & leveling	2 days	2 days	4 days	4 days	6 days
Water depth at planting, cm	_	_	1-2	1-2	3-4

Table 4.13 Machine performance parameters of different rice cultivation method

Parameters	Direct seeding		Mechanical transplanting		Manual transplanting
	Male	Female	Male	Female	
No. of seedlings/hill	5-6	5-6	3-5	3-5	2-3
No. of hills/m^2	28	27	32	30	29
Planting depth, cm	_	_	2-5	2-5	1-2
Row spacing, cm	20	20	30	30	_
Average hill spacing, cm	22	21.6	13.8	13.8	22.6
Working speed, km h^{-1}	1.04	1.01	1.37	1.30	0.21
Actual working time	9 min 36 sec	10 min 12 sec	8 min 32 sec	9 min 10 sec	47 min 16 sec
Extra Time	3 min 40 sec	4 min 55 sec	6 min 18 sec	5 min 36 sec	_
TFC, ha h^{-1}	0.17	0.16	0.16	0.15	_
EFC, ha h^{-1}	0.12	0.10	0.12	0.11	0.02
Field efficiency, %	71	67	75	73	_
Fuel consumption, *l* ha^{-1}	_	_	3.7	3.7	_
Labour requirement	1	1	2	2	2

Table 4.14 Yield parameters of different rice cultivation method

Parameters	Direct seeding		Mechanical transplanting		Manual transplanting
	Male	Female	Male	Female	
No. of tillers/m2	640	660	672	675	522
No. of panicles/m2	512	540	588	567	348
Grain yield (kg ha^{-1})	2255	2275	2635	2669	2025
Straw yield (kg ha^{-1})	2876	2894	3466	3498	2508



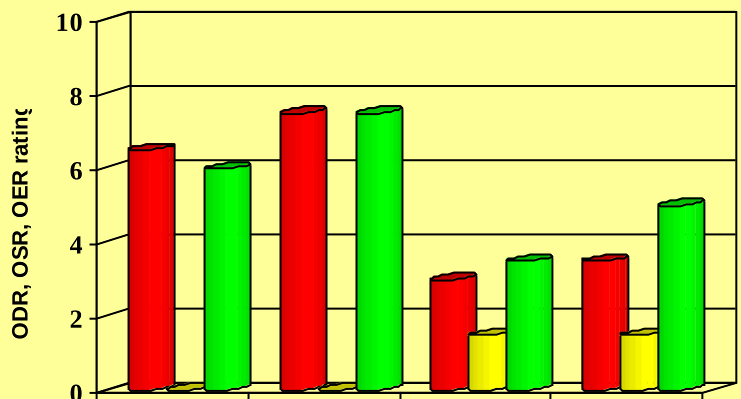
	Direct seeding	Mechanical transplanting	Manual transplanting
Grain yield	2265	2652	2025
Straw yield	2885	3482	2508

Fig 4.3 Grain yield and straw yield comparison

The yield parameters of different methods of rice cultivation are presented in Table 4.14. The mean number of panicles per square meter obtained was significantly more in case of mechanical transplanting (673) than direct seeding (650) and manual transplanting method (522). The data indicated that the grain and straw yield were maximum with mechanical transplanting followed by direct seeding compared to manual transplanting. This may be attributed to higher number of tillers/m^2 in case of mechanical transplanting.

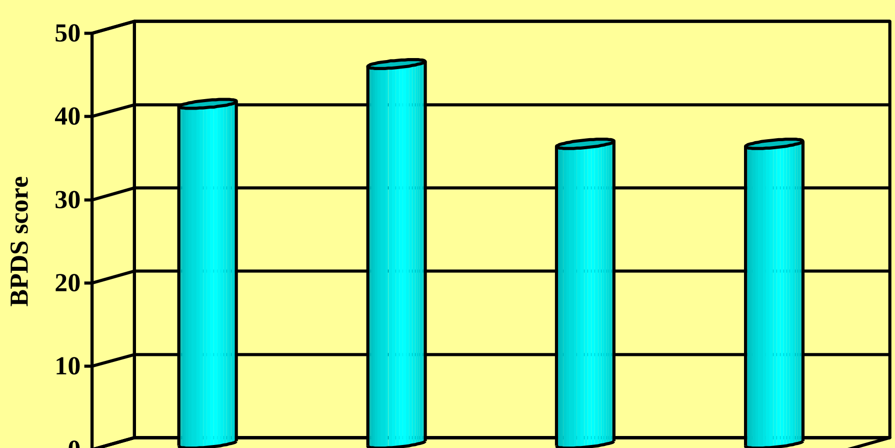
Table 4.15 Ergonomic parameters of Direct Seeder and Mechanical Transplanter

Parameters	**Direct Seeder**		**Mechanical Transplanter**	
	Male	**Female**	**Male**	**Female**
HR, beats min^{-1}	145.5	148.9	131.6	134.1
OCR, *l* min^{-1}	0.95	0.98	0.80	0.83
ODR	6.5	7.5	3.0	3.5
OSR	0	0	1.5	1.5
OER	6.0	7.5	3.5	5.0
BPDS	40.8	45.6	36	36



	Direct seeder Male	Direct seeder Female	Mechanical transplanter Male	Mechanical transplanter Female
ODR	6.5	7.5	3	3.5
OSR	0	0	1.5	1.5
OER	6	7.5	3.5	5

Fig 4.4 Comparison of ODR, OSR, OER for direct seeder and mechanical transplanter



	Direct seeder Male	Direct seeder Female	Mechanical transplanter	Mechanical transplanter
BPDS	40.8	45.6	36	36

Fig 4.5 Comparison of BPDS for direct seeder and mechanical transplanter

4.6 Comparison economics of rice cultivation by different method

Table 4.16 Comparison economics of rice cultivation per ha by different method

Operations	Direct seeding		Mechanical transplanting		Manual transplanting	
	Labour cost `	Input cost `	Labour cost `	Input cost `	Labour cost `	Input cost `
Nursery Raising	_	1036	170	1540	450	2016
Main land preparation	715	1170	715	1170	715	1170
Planting	460	78	667	4300	6945	_
Fertiliser application	500	5015	500	5015	500	5015
Weeding	5600	_	3200	_	4800	_
Plant protection	250	3055	250	3055	250	3055
Harvesting	420	1195	420	1195	420	1195
Threshing	1575	_	1575	_	1575	_
Total cost (` ha^{-1})	21069		23772		28106	
Grain yield (kg ha^{-1})	2265		2652		2025	
Income-grain (` ha^{-1})	33975		39780		30375	
Straw yield (kg ha^{-1})	2885		3482		2508	
Income-straw (` ha^{-1})	8655		10446		7524	
Gross return	42630		50226		37899	
Net returns	21561		26454		9793	
B-C ratio	1:2.02		1:2.11		1:1.35	

∗ Values under consideration:

Men Labour: ` 500/day, Women Labour: ` 500/day, Seed: ` 28/kg,
Grain: ` 15/kg and Straw: ` 3/kg

The economic feasibility of different rice cultivation methods is presented in Table 4.16. The gross returns were more in case of mechanical transplanting than other methods. Mechanical transplanting method was recorded higher gross returns of ` 50226 $ha^{-1}$ than direct seeding (` 42630 ha^{-1}) and manual transplanting

(` 37899 $ha^{-1}$). Similarly, net returns were also higher in the case of mechanical transplanting (` 26454 ha^{-1}) than direct seeding (` 21561 $ha^{-1}$) and manual transplanting (` 9793 ha^{-1}). Further, the cost of cultivation was lower in the case of direct seeding mainly because of absence of operations like nursery raising and transplanting. In case of mechanical transplanting reduction in cost of labours for operations like planting and weeding considerably reduces the total cost. Cost of cultivation per ha for manual transplanting, direct seeding and mechanical transplanting are respectively as ` 28106, ` 21069 and ` 23772.

The cost of transplanting per ha by using a mechanical transplanter was ` 4968 as compared to ` 537 with direct seeding. Among the different rice farming practices studied, mechanical transplanting method fetched the maximum gross returns, net profit and B:C (1:2.11) ratio. Least gross returns, net profit and B:C (1:1.35) ratio were recorded in manual transplanting (Table 4.16).

CHAPTER 5
SUMMARY AND CONCLUSION

Transplanting is a tedious operation which is normally performed by women labourers in upright bending posture. A woman labour has to dip her hand 6000-7000 times per hour for transplanting of paddy seedlings in standing water. This posture when continued for years together results in low back pain (LBP) and spinal disorders. This arduous operation can be made more comfortable by the use of direct paddy seeders and mechanical transplanter. In order to get the best comfort to operators and to get more yields, a study on performance and ergonomic evaluation of direct paddy seeder and mechanical rice transplanter was carried out at the instructional farm, KCAET, Tavanur.

The level of energy expenditure in agriculture is high, as it is a labour intensive occupation. There are now an increasing number of examples of ergonomics interventions in agricultural operations where performance or health and safety have been improved. Ergonomics will be regarded as a useful input only if its potential and promises are delivered. The ergonomic evaluation was conducted to ascertain the improved comfort, safety and ease of operation.

The study was envisaged to compare the performance of two equipments viz., 8 row direct paddy seeder and walk behind type mechanical transplanter, used for raising paddy in wet lands. The operator’s comfort in using these machines by male and female subjects was evaluated from ergonomic point of view. The parameters used for the ergonomical evaluation include the heart rate, oxygen consumption rate and energy cost of operation, overall discomfort rating, body part discomfort score, overall safety rating and overall ease of operation rating. The subjects were selected for the investigation based on their age and fitness. Subjects within the age range of 25 to 35 years and having well physical and mental health were selected.

Performances of the two selected equipments in terms of machine, seed, crop and yield parameters were compared with traditional manual transplanting.

The experimental plot was divided into four equal sizes of 270 m^2 each for conducting trials with mechanical transplanter and direct seeder using male and female subjects. An area of 200 m^2 was kept for manual transplanting. The soil type was sandy loam in texture comprising of 10% gravel, 65% sand, 12.5% silt and 12.5% clay. Paddy variety used for the study was 'Jyothi', the second most popular rice variety of Kerala, released from RARS, Pattambi.

Mat nursery for mechanical transplanting was prepared using tray nursery raising machine. The nursery thus prepared was maintained properly for 15 days for growth of seedling. Traditional nursery was raised for manual transplanting on beds of 3 cm height, 1.2 m wide and 10 m long with drainage channels between the beds. Sprouted seeds were evenly spread over the seed bed for traditional nursery. The experimental field was ploughed and leveled by using tractor mounted rotavator. The field was well nourished with organic manure and puddled with tractor cage wheels. The field for mechanical transplanting was drained out and allowed to settle for 2 days after final puddling so as to make the subsurface soil layer hard enough to support the transplanting machine. A thin layer of water is allowed at the time of transplanting.

The machine transplanting was done by using a 'Mahindra - PF 455 S' four row rice transplanter. It is a walk behind type rice transplanter using mat type nursery and it transplants the seedling uniformly without damaging them. It has a fixed row to row spacing of 30 cm and hill to hill spacing can be varied. In the experiment the hill to hill spacing was fixed as 13.8 cm to a corresponding speed range of 1.22 to 2.66 km h^{-1}. Automatic depth control helped in maintaining uniform planting depth. The machine has safety clutch mechanism, which prevents break down of planting device from the impact against stones in the field. The mechanical rice transplanter was initially tested in the laboratory to check the working of all the functional components. Fifteen days old seedling mats were taken out from the seedling tray and placed it on the mechanical transplanter. Transplanting was carried out by mechanical transplanter length wise in the prepared field by male and female subjects separately.

For direct seeding, water was drained out for 24 hrs before sowing to form hard slurry pan of the puddle soil. At the time of sowing thin film of water was maintained in the puddle field. An eight row improved drum seeder of ‘Aiswarya’ make was used for direct seeding of pre-germinated paddy seeds. The row-to-row spacing of direct seeding was 20 cm. Major components of the drum seeder were made up of high density plastic and the shaft and handle are made of mild steel. Each seed drum drops two rows of seeds and four such drums gives 8 rows of seeding at a time. Wheels are provided at both ends of a square shaft. These wheels are made up of high density plastic material to reduce the weight of the equipment. The seeds just started sprouting was filled in the drum to two third of its capacity in order to facilitate easy flow of seeds through the holes of the drum. The seeder was then pulled at a speed of about 1 km h^{-1} in the prepared field and the seeds were dispensed by the action of gravity. The experiment was carried for male and female subjects separately.

In manual transplanting, seedlings were pulled out at 4 to 5 leaf stage of the nursery. Seed bed was irrigated a day before pulling out the seedlings to soften the soil and to facilitate washing of roots. Soil is washed off from the roots carefully and grouped the seedlings into bundles of convenient size for transporting to main field. The seedlings were then transplanted in the prepared field. Two to three seedlings per hill were transplanted at shallow depth and at random spacing. Seedlings were handled carefully to ensure the fast revival and rapid growth after transplanting.

Performance indices such as seed rate, seedling per hill, plant population, missing hills, theoretical field capacity, speed of operation, effective field capacity, field efficiency, fuel consumption, grain yield and straw yield were determined for both equipments.

Nitrogen, phosphorous and potassium fertilizers were applied at the rate of 70:35:35 kg ha^{-1}. Irrigation was done depending on the height of the seedlings water was allowed to stand in the field. A cono-weeder was used for weeding between rows of paddy. Harvesting was carried out by KAMCO power reaper KR-120 manufactured by Kerala Agro Machinery Corporation Ltd. The crop was threshed and weighed for grain and straw yields.

Ergonomic evaluation of these operations by male and female subjects were carried out by collecting data on heart rate, oxygen consumption rate, energy cost of operation, overall discomfort rating, body part discomfort score, overall safety rating and overall ease of operation rating.

The heart rate was measured using Polar S 810 heart rate monitor. The OCR and energy consumption was calculated by using the empirical relations based on the height/weight ratio suggested by Phillip (2001). The ODR, OSR and OER were measured using a standard 10 point scale as suggested by Corlett and Bishop (1976). BPSD was measured by recording the response of the subjects using a standard BPDS body map.

5.1 Performance evaluation of Direct paddy seeder and mechanical transplanter

i. Seed rate for direct paddy seeder was 37 kg ha^{-1}. For mechanical transplanter it comes to 55 kg ha^{-1} and for manual transplanting is 72 kg ha^{-1}.
ii. The number of seedlings per hill obtained was 3-5 for mechanical transplanting and 2-3 for manual transplanting. It was observed that 5-6 seeds dropped per hill while operating the direct seeder.

iii. It was observed that there were 27 hills per square meter in direct seeding, 31 in mechanical transplanting and 29 in manual transplanting.

iv. The missing hills in direct seeder and mechanical transplanter were 2.80% and 1.60% but in case of manual transplanting method, the missing hill was nil.

v. The theoretical field capacity of direct seeder and mechanical transplanter was 0.16 ha $h^{-1}$and 0.15 ha h^{-1} respectively.

vi. The speed of direct seeder in the field was 1.02 km h^{-1}. The speed of mechanical transplanter in the field was 1.33 km h^{-1}.

vii. Effective field capacity calculated for direct seeder and mechanical transplanter was 0.11 ha $h^{-1}$and 0.12 ha h^{-1} respectively. The EFC value for manual transplanting was found to be 0.02 ha h^{-1}.

viii. The field efficiency was found to be 69% for direct seeder and 74% for mechanical transplanter.

ix. Fuel consumption of mechanical transplanter was 3.7 *l* ha^{-1}.

x. The mean grain yield in mechanical transplanting method was higher 2652 kg ha^{-1} as compared to 2265 kg ha^{-1} for drum seeding and 2025 kg ha^{-1} for manual transplanting respectively.

xi. The straw yield was highest for mechanical transplanting method (3482 kg ha^{-1}) as compared to direct seeding (2885 kg ha^{-1}) and manual transplanting (2508 kg ha^{-1}).

5.2 Ergonomic evaluation of Direct paddy seeder and mechanical transplanter

i. The age of the selected male and female subjects was in the range 25 and 35 years.

ii. The average working heart rate (HR work) of the subjects when operating direct seeder was 145.5 and 148.9 beats min^{-1} for male and female subjects respectively. The corresponding values when the mechanical transplanter was operated were 131.6 and 134.1 beats min^{-1} for male and female respectively.

iii. HR work steadied after 6 minutes of operations and there was complete recovery of HR after 8 min with direct seeder and 6 min with mechanical transplanter.

iv. The OCR of male and female subjects, for 8 row direct seeder has found to be 0.95 *l* min^{-1} and 0.98 *l* min^{-1} respectively. But in case of 4 row mechanical transplanter, the OCR observed to be 0.80 and 0.83 *l* min^{-1} for male and female subjects respectively.

v. Energy requirment of male and female subjects for direct seeder has found to be 19.05 kJ min^{-1} and 19.74 kJ min^{-1} respectively and it is graded as “very heavy”. But for mechanical transplanter it was 16.23 kJ min^{-1} and 16.74 kJ min^{-1} for male and female subjects respectively and graded as “heavy” only. The energy demand required for manual transplanting is approximately 11.15 kJ min^{-1} and it is graded as “moderate”.

vi. The values of overall discomfort rating of the male were observed to be 6.5 for direct seeder and 3.0 for mechanical transplanter. These values for female subject were 7.5 for direct seeder and 3.5 for mechanical transplanter. It is observed that the overall discomfort experienced by the both subject was less for mechanical transplanter compared to direct paddy seeder.

vii. The values of BPDS of the both male and female subjects were observed as 40.8 and 45.6 respectively for direct seeder and for mechanical transplanter the BPDS were 36 for both subjects. It is observed that the BPDS of male and female subjects were maximum for the direct seeder.

viii. The values of OSR of male and female subjects for direct seeder were found to be zero (0). But for mechanical transplanter it was found to be 1.5 for both male and female subjects. From OSR it observed that the direct seeder is completely secure with no fear and mechanical transplanter is ‘secure and meager fear’.

ix. The values of OER for the male subject were observed to be 6.0 and 3.5 for direct seeder and mechanical transplanter respectively. These values for female subject were observed to be 7.5 and 5.0 respectively for direct seeder and mechanical transplanter. For both subjects, walk behind mechanical transplanter is comparatively easier than pulling direct seeder.

From the study, it can be concluded that the self-propelled 4 row Mahindra walk behind mechanical transplanter could be used successfully not only to improve the yield but also to provide operator comfort as compared to the 8 row direct seeder. The field efficiency of the mechanical transplanter was found satisfactory and it is easy to operate. The 8 row direct seeder is not suitable for female subjects.

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APPENDIX I

Specification of tray nursery raising machine

Particular	Dimension
Korean make	
Length	7.25 m
Width	48 cm
Height	105 cm
Motor	0.3 kW
Tray	30 cm × 60 cm
Capacity	600 trays per h
Tray requirement for 1 ha	200

APPENDIX II

Technical specification of vertical conveyor power reaper

Parameters	Specifications
Manufacturer	Kerala Agro Machinery Corporation Ltd., (A Govt. of Kerala undertaking), Athani, Ernakulam.
Model	KR 120
Dimension, LxWxH (mm)	2390 x 1470 x 900
Weight (kg)	116
Power unit	3.5 HP single cylinder 4 stroke, air cooled, petrol start, kerosene run engine
Working capacity (ha h^{-1})	0.25 to 0.30
Crop release	Right side of the machine
Travel speed (km h^{-1})	Forward 3.5, Backward 3.0
Applicability	Dry and wet field
Cutting device	Reciprocating knife bar
Cutting height (cm)	10-30 from ground level (adjustable)
Cutting width (cm)	120

APPENDIX III

Heart rate

Time	Direct seeder male	Direct seeder female	Mechanical transplanter male	Mechanical transplanter female
0	67	71	67	71
1	84	87	76	81
2	97	99	87	94
3	108	111	95	99
4	121	127	107	111
5	134	139	116	118
6	143	147	127	130
7	147	149	130	134
8	148	150	131	134
9	147	150	132	136
10	148	149	132	135
11	147	151	133	135
12	149	150	132	137
13	146	149	133	136
14	147	148	134	139
15	133	146	119	125
16	121	133	107	111
17	110	120	94	103
18	103	108	83	91
19	91	97	72	80
20	79	83	67	71
21	72	76	-	-
22	67	73	-	-
23	-	71	-	-

APPENDIX IV

BPDS for direct paddy seeder and mechanical rice transplanter

<table>
<tr><th rowspan="2">Equipment</th><th rowspan="2">Subject</th><th colspan="5">Category</th><th rowspan="2">Total score</th></tr>
<tr><th>I(6)</th><th>II(4.8)</th><th>III(3.6)</th><th>IV(2.4)</th><th>V(1.2)</th></tr>
<tr><td rowspan="4">Direct seeder</td><td rowspan="2">Male</td><td>26,27</td><td>10,11</td><td>22,23</td><td>20,21,4,5</td><td>24,25</td><td rowspan="2">40.8</td></tr>
<tr><td>12</td><td>9.6</td><td>7.2</td><td>9.6</td><td>2.4</td></tr>
<tr><td rowspan="2">Female</td><td>10,11</td><td>26,27, 24,25</td><td>4,5</td><td>14,15</td><td>20,21</td><td rowspan="2">45.6</td></tr>
<tr><td>12</td><td>19.2</td><td>7.2</td><td>4.8</td><td>2.4</td></tr>
<tr><td rowspan="4">Mechanical Transplanter</td><td rowspan="2">Male</td><td>8,9</td><td>22,23</td><td>24,25</td><td>14,15</td><td>10,11</td><td rowspan="2">36</td></tr>
<tr><td>12</td><td>9.6</td><td>7.2</td><td>4.8</td><td>2.4</td></tr>
<tr><td rowspan="2">Female</td><td>4,5</td><td>22,23</td><td>24,25</td><td>14,15</td><td>8,9</td><td rowspan="2">36</td></tr>
<tr><td>12</td><td>9.6</td><td>7.2</td><td>4.8</td><td>2.4</td></tr>
</table>

Score= 6/category = 6/5 = 1.2

- I= 6
- II= 4.8
- III= 3.6
- IV= 2.4
- V= 1.2

APPENDIX V

Cost of operation

Title	Tractor	Rotavator	Direct seeder	Mechanical Transplanter	Power Reaper
New cost, P	400000	115000	4500	250000	50000
Life (yrs), L	10	8	5	10	10
Avg. use/yr (h)	1000	300	100	100	200
Rate of interest (%), i	12	12	8	10	10
Field capacity, ha h^{-1}	0.2	0.35	0.18	0.15	0.2
Salvage value, S=10% of P	40,000.00	11,500.00	450.00	25,000.00	5,000.00
Annual Fixed Charges					
Depreciation (` yr^{-1})	36,000.00	12,937.50	810.00	22,500.00	4,500.00
Interest cost (` yr^{-1})	26,400.00	7,590.00	198.00	13,750.00	2,750.00
Taxes, insurance and shelter (` yr^{-1}) = 2% of P	8000	2300	90	5000	1000
Total fixed costs (` yr^{-1})	70,400.00	22,827.50	1,098.00	41,250.00	8,250.00
Total fixed costs (` h^{-1})	70.4	76.09167	10.98	412.5	41.25
Variable Costs					
Repair & maintenance (` h^{-1})	20	19.16667	2.25	125	12.5
Fuel required (*l* h^{-1})	3	0	0	3.7	5.5
Fuel cost (` h$^{-1}$) = fuel required (*l* h$^{-1}$) x price of fuel (` *l*$^{-1}$) @ ` 28 *l*$^{-1}$	123.9	0	0	103.6	154
Cost of lubricants (` h^{-1}) = 20% of fuel cost	24.78	0	0	20.72	30.8
Labor cost (` h^{-1})	83.33	0.00	83.33	83.33	83.33
Total variable cost (` h^{-1})	252.01	19.17	85.58	332.65	280.63
Total Costs					
Total cost (fixed + variable) (` h^{-1})	322.41	95.26	96.56	745.15	321.88
Total cost, ` ha^{-1}	1612.05	272.17	536.44	4967.67	1609.40

ABSTRACT

An experiment was conducted to evaluate the performance of the 'Aiswarya' 8 row direct seeder and 'Mahindra PF455S' 4 row walk behind mechanical transplanter with 'Jyothi' rice variety in wet lands from the ergonomic point of view. It conducted with selected male and female subjects in the age group of 25–35 years. The performance of these machines was compared with manual transplanting. The results show that the seed rate for direct seeder was very low with 37 kg ha^{-1} as compared to the mechanical transplanter (55 kg ha^{-1}) and manual transplanting (72 kg ha^{-1}). EFC found for direct seeder and mechanical transplanter was 0.11 ha $h^{-1}$and 0.12 ha h^{-1} respectively. The field efficiency was found to be 69% for direct seeder and 74% for mechanical transplanter. Fuel consumption of the mechanical transplanter was found 3.7 *l* ha^{-1}. The grain yield and straw yield in mechanical transplanting method was higher 2652 kg ha^{-1} and 3482 kg ha^{-1} as compared to 2265 kg ha^{-1} and 2885 kg ha^{-1} in the case of direct seeding. But in the case of manual transplanting, the yields were 2025 kg ha^{-1} and 2508 kg ha^{-1} respectively. The mean value of WHR and OCR with direct seeder was 145.5 beats min^{-1} and 0.95 *l* min^{-1} for male and 148.9 beats min^{-1} and 0.98 *l* min^{-1} for female. But in case of mechanical transplanter, the mean value of WHR and OCR was 131.6 beats min^{-1} and 0.80 *l* min^{-1} for male and 134.1 beats min^{-1} and 0.83 *l* min^{-1} for female. There was complete recovery of HR after 8 min with direct seeder and 6 min with mechanical transplanter. In case of direct seeder ODR, OSR, OER, BPDS values were given by male 6.5, 0, 6.0, 40.8 and by female 7.5, 0, 7.5, 45.6. The corresponding values for mechanical transplanter were 3.0, 1.5, 3.5, 36 by male and 3.5, 1.5, 5.0, 36. As per the grading of energy cost of work, direct seeder categorized as "very heavy type" and mechanical transplanter as "heavy type". The 8 row direct seeder is not suitable for female subjects. A 4 row Mahindra walk behind mechanical transplanter could be used successfully not only to improve the yield but also to provide operator comfort as compared to the 8 row direct seeder.

PERFORMANCE AND ERGONOMIC EVALUATION OF DIRECT PADDY SEEDER AND MECHANICAL RICE TRANSPLANTER IN WET LANDS

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