PERFORMANCE OF DIFFERENT VARIETIES IN DIRECT SEEDED RICE (*Oryza sativa* L.) AS AFFECTED BY DIFFERENT SOWING METHODS

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PERFORMANCE OF DIFFERENT VARIETIES IN DIRECT SEEDED RICE (*Oryza sativa* L.) AS AFFECTED BY DIFFERENT SOWING METHODS

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the Degree of Master of Agricultural Science (Agronomy)

Department of Agronomy
Yezin Agricultural University
Yezin, Nay Pyi Taw

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The thesis attached hereto, entitled **"Performance of Different Varieties in Direct Seeded Rice (*Oryza sativa* L.) As Affected by Different Sowing Methods"** was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Agronomy).**

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DECLARATION OF ORIGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS, U SAN LWIN

AND DAW CHO CHO AND BELOVED WIFE,

DAW NI RAW DA MYINT THEIN

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ABSTRACT

Field experiments were conducted in DaikU Township of Bago (East) Region and Maubin Township of Ayeyarwaddy Region from November, 2015 to April, 2016 with two objectives: (1) to compare the different sowing methods on performance of tested rice varieties, (2) to investigate the effect of sowing methods on yield and yield components of tested rice varieties in direct seeded summer rice area of Maubin and DaikU Townships. These experiments were laid out in split-plot design with three replications in both sites. Three different rice varieties (Theehtatyin, Yeanelo 4 and Yeanelo1) were assigned in main plot and three different sowing methods (Broadcasting, Line sowing and Drum seeder) were arranged in sub plot. According to the result of the experiments, in DaikU Township, Yeanelo 1 gave the highest grain yield (4.75 t ha^{-1}) with the maximum number of spikelets $panicle^{-1}$, filled grain percentage, panicle length and harvest index and in Maubin Township, Theehtatyin variety obtained highest grain yield (6.32 t ha^{-1}) with the highest number of panicles m^{-2} and harvest index among the different rice varieties. And then, Theehtatyin variety showed significantly increases in number of spikelets $panicle^{-1}$ and filled grain percentage in comparison with the DaikU experiment. Number of spikelets $panicle^{-1}$ was negatively correlatively with the number of effective panicles m^{-2} for all tested rice varieties and sowing methods. Regarding the different sowing methods, Drum seeder supported to produce higher grain yield than that of Line sowing and Broadcasting. Although Drum seeder made to produce low panicles numbers m^{-2}, other yield component such as number of spikelets $panicle^{-1}$ and agronomic characters such as panicle length and harvest index were found to have highest among the tested sowing methods in both locations. Besides, there was no significantly difference in filled grain percentage among the sowing methods. Therefore, it can be concluded that Yeanelo 1 variety for DaikU Township and Theehtatyin variety for Maubin Township should be sown by using Drum seeder methods gave the maximum grain yield with better performance.

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CHAPTEER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important staple food of about half of the world population. Asia is the leader in rice production and accounts for more than 90% of world rice production (Bhambhro 2001). In Myanmar, actual paddy sown areas in 2015-2016 was 7.17 million hectares with the national average yield of 3.94 MT ha^{-1} and production reached at 28.21 million metric tons (MOALI 2016). Ayeyarwaddy and Bago regions are the most widely rice grown regions (DoA 2014).

To meet the increasing demand for rice and to sustain exports, Myanmar embarked on rice production through area expansion, yield increase, and crop intensification in the early 1990s. The area under rice was increased from 4.8 to 6.0 million hectares during 1990 to 1994, which raised annual rice production from 14.0 to 17.9 million ton within a four year period. Rice production in Myanmar rapidly increased during first half of the 1990s as a result of an expansion in growing area of irrigated summer rice (IRRI 2007).

To generate increased production of paddy, measures are being taken by the Ministry of Agriculture and Irrigation in growing high yielding varieties, including introduction of hybrid rice varieties (MOAI 2014). The choice of variety is made by farmers based on a combination of factors that include: (1) adaptation to the growing environment, (2) eating/cooking preferences of the consumers, (3) market preference/price, and (4) cost of seed. Modern rice varieties, High Yielding Varieties, (also known as HYVs) are variously reported to be used for 70-80% of the monsoon crop and for virtually all the summer crop. HYVs are widely grown in the summer season because of their early maturity and the absence of flooding risk at that time of year (Denning et al. 2013).

High yielding varieties (HYVs) are used for both transplanting and wet seeded rice (WSR) cultivation in Myanmar. Most of the varieties used for summer rice are high yielding varieties (HYVs). The first introduction of a HYV to Myanmar was IR-8 in 1ater new HYVs were systematically introduced in 1970s (Young et al. 1998). De Datta (1981) reported that early maturing rice cultivars (about 100-day duration) were preferred for WSR.

In Myanmar, wet seeding is more common for summer rice crop. This is because of the lower likelihood of submergence and related mortality of young seedlings. Higher seeding rate is one approach that helps increase crop competitiveness against weeds. High seeding rates facilitate quick canopy closure, which helps suppress weeds more effectively. High seeding rates improve the ability of crops to suppress weeds and can reduce yield loss under partially weedy conditions. At low seeding rates, crop plants take more time to close their canopy, which encourages weed growth. Without optimum plant population, a cultivar cannot give maximum genetic potential. Optimum plant population contributes to high yield, which relates directly to seeding density (Janoria 1989).

Wet seeded rice (WSR) area in Myanmar constitutes 30% in monsoon and 80% in summer of the concerned rice area in 2001-2002 (AED 2002). There are three principal methods of rice establishment; dry seeding consists of sowing dry seeds on dry soil; wet seeding, involves sowing pre-germinated seeds in wet puddled soils; transplanting involves, replanting of rice seedlings grown in nursery to puddled soils (Mishri and Kailash 2005). Tin Maung Bo and Hla Min (1995) expressed that there were different planting methods of WSR in Myanmar; broadcasting (WSR-B), line seeding (WSR-L) and spot seeding or hill-wise seeding (WSR-S).

The seed may be broadcasted by hand or less commonly using a seeder. The Drum seeder was widely distributed in Myanmar through Livelihoods and Food Security Trust Fund (LIFT) and implementing partners with mixed results (Barca 2012). In area where broadcast seeding is practiced, the Drum seeder offers several advantages. It reduces seeding rate to about 50-100 kg ha^{-1} without compromising yield (broadcast seeding rate requires 100-150 kg ha^{-1}). Saving in seed costs are realized. Drum seeder increases yield due to better weed control (i.e., facilitates use of mechanical weeders), better fertilizer and sunlight distribution due to less crowded plants.

The main change in the Delta is migration to labour opportunities mostly in Yangon. Landless households are increasingly mobile, many choosing to leave agricultural labour. Farmers are mostly rice-based with a limited level of diversification. Farmers are facing rising labour costs and difficulties to access labour on time, especially between the monsoon and winter seasons. The adoption of new rice varieties and alternative crop management options can advance the rice harvest, provide options for post-rice crops and lead to greater diversification for small-holder farmers in the Ayeyarwaddy Delta. Therefore, the study was carried out with the following objectives:

- to compare the different sowing methods on performance of tested rice varieties in DaikU and Maubin Township, and
- to investigate the effect of sowing methods on yield and yield components of tested rice varieties in both locations.

CHAPTER II
LITERATURE REVIEW

2.1 Methods of Rice Establishment

2.1.1 Transplanted rice (TPR)

Rice cultivation is done in different ways in the world. The most important cultivation ways are transplanting and direct seeding methods. Transplanting is a resource and cost intensive method since the preparation of seedbed, the raising of seedling and the transplanting are labor and time intensive operations (Rana et al. 2014).

Although manual transplanting is the common method of rice cultivation but it is too much laborious, cumbersome (slow and inefficient), time consuming and entails a lot of expenditure on raising, uprooting and transplanting of nursery. Also, transplanting has added disadvantages such as stress on seedlings and raising nurseries. Despite the fact that mechanized transplanting is the best method of plant establishment, it is not feasible to introduce it at this moment due to lack of local technology and also due to high machinery cost which farmers cannot afford. Careless transplanting by hired labor results in low planting densities in the farmer's field. The scarcity and high cost of farm labor invariably delays transplanting and often leads to the use of aged seedlings (Santhi et al. 1998) which causes low yield (Om et al.1993). Manual transplanting results in yield reductions due to low plant population.

To solve the problem of the labor shortage, alternate methods of rice establishment are inevitable. At present, rice cultivation is as direct seeded in America, Western Europe such as Italy and French, Russia, Japan, Cuba, India, Korea, and the Philippines and in some parts of Iran, due to high technology, high labour cost and shortage of skilled labour (Akhgari 2004).

2.1.2 Direct seeded rice (DSR)

Direct seeding of rice refers to the process of establishing the crop from seeds sown in the field rather than by transplanting seedlings from the nursery (Farooq et al. 2011). Prior to the 1950s, direct seeding was most common, but was gradually replaced by puddled transplanting (Pandey and Velasco 2005; Rao et al. 2007). DSR is a major opportunity to change production practices to attain optimal plant density and high water productivity in water scarce areas. Adoption of DSR for lowland rice culture would significantly decrease costs of rice production (Flinn and Mandac 1986). Direct seeding is the oldest method of rice establishment. It was traditionally practiced before transplanting.

Adair et al. (1992) reported that direct seeding of rice is a potential alternate, which, is a successful method in various rice growing countries of the world. Nguyen and Ferrero (2006) indicated that the final rice cultivation system in the world is affected by the water deficiency, the low suitable land, and shortages of worker. Mahajan et al. (2006) supposed that direct seeding of rice is the water and labor saving technique of cultivation. It eliminates the need of seedling rising, maintaining and subsequent transplanting. In addition to higher economic returns, directly seeded crops are faster and easier to plant, less labor intensive and consume less water (Jehangir et al. 2005). Directly seeded rice has received much attention all over the word by the agronomist because of its low input demand.

In many parts of the world alternative methods such as manual or mechanized broadcasting are being practiced. It is an old method of planting rice, a good option for very clear reason, where, reduction of labor cost, though it has many disadvantages such as excessive seed usage and high plant density which leads to competition among plants. Isvilanonda (2002) reported that direct seeded rice reduced 2-6% production cost and increased net return by 37%, in dry season.

2.2 Types of Direct Seeded Rice

2.2.1 Dry direct seeding

Dry seeding has been the principal method of rice establishment since the 1950s in developing countries (Pandey and Velasco 2005). In Dry-Direct Seeded Rice (Dry-DSR), rice is established using several different methods, including (1) broadcasting of dry seeds on unpuddled soil after either zero tillage or conventional tillage, (2) dibbled method in a well-prepared field, and (3) drilling of seeds in rows after conventional tillage, reduced tillage using a power-tiller-operated seeder (PTOS). In Dry-DSR, land preparation is done before the onset of monsoon, and seeds are sown before the start of the wet season to take advantage of pre-monsoon rainfall for crop establishment and early crop growth. This method is traditionally practiced in rainfed upland, lowland, and flood prone areas of Asia (Rao et al. 2007). However, it was recently importance in irrigated areas where water is becoming scarce.

2.2.2 Wet direct seeding

In contrast to Dry-DSR, Wet-DSR involves sowing of pre-germinated seeds with a radicle varying in size from 1 to 3 mm on or into puddled soil. When pre-germinated seeds are sown on the surface of puddled soil, the seed environment is mostly aerobic and this is known as aerobic Wet-DSR. In both aerobic and anaerobic Wet-DSR, seeds are either broadcast or sown in-line using a Drum seeder (Khan et al. 2009; Rashid et al. 2009) or an anaerobic seeder with a furrow opener and closer (Balasubramanian and Hill 2002). When manual broadcasting is done, seeds are soaked in water for 24 h followed by incubation for 24 h. However, when motorized broadcasting is done, the pregermination period is shortened (24-h soaking and 12-h incubation) to limit root growth for ease of handling (easy flow of sprouted seeds) and to minimize damage, as is the case when a Drum seeder is used for row seeding (Balasubramanian and Hill 2002). Wet-DSR is primarily done under labour shortage situation, and is currently practiced in Malaysia, Thailand, Vietnam, Philippines, and Sri Lanka (Pandey and Velasco 2002; Weerakoon et al. 2011).

2.2.3 Water seeding

Water seeding has gained popularity in areas where red rice or weedy rice is becoming a severe problem (Azmi and Johnson 2009). Aerial water seeding is the most common seeding method used in California (United States), Australia, and European countries to suppress difficult-to-control weeds, including weedy rice. This method is also becoming popular in Malaysia. In this method, pregerminated seeds (24-h soaking and 24-h incubation) are broadcast in standing water on puddled (Wet water seeding) or unpuddled soil (Dry water seeding). Normally, seeds, because of their relatively heavy weight, sink in standing water, allowing good anchorage. The rice varieties that are used possess good tolerance of a low level of dissolved oxygen, low light, and other stress environments (Balasubramanian and Hill 2002).

2.3 Methods of Direct Seeded Rice

2.3.1 Broadcasting

Broadcasting in wet conditions (wet seeding) is the principal method of rice establishment. In this method, pregerminated seeds are sown on to wet (saturated) puddled soils. But, some difficulties are faced in wet seeding. The use of high seeding rate in a broadcast culture may increase the gap between farmers' potential and actual yield. In broadcasting method the seeds fall at different depths resulting in uneven crop stand, which ultimately affects the crop yield (Reddy and Reddi 2002). Thus, selection of proper sowing method is necessary to ensure proper plant population, synchronization of tillering, flowering; maturity and reaping bumper yield of rice.

2.3.2 Line sowing

Drilling the seeds in lines is an improved method over that of broadcasting in which the seed rate is generally reduced**.** Drill seeding is preferred over broadcasting in irrigated or favorable rainfed areas in both developed and developing countries as it allows Line sowing and facilitates weed control between rows, saves seeds and time, and provides better crop establishment. Sowing the crop in lines facilitates uniform depth and spacing resulting in fast and uniform crop emergence and establishment leading to higher crop yields. Line seeders have been introduced by various institutes and personals over the past decades in order to achieve aforementioned requirements. All of them have advantages as well as unique disadvantages. As such, line seeding is still not popular among farmers. Furthermore, numbers of researchers have reported that the direct sowing of paddy rice using a Drum seeder has resulted in lower cost of production and higher yield as compared to manual transplanting (Devnani 2002; Johnkutty et al. 2002).

2.3.3 Drum seeder

Direct seeding by using single thick row of Drum seeder produced about 21% higher yield than transplanted rice (Hussain et al. 2004). Drum seeder is light in weight, easy to operate and more area can be covered by a single man. Advantages of Drum seeder is uniformity in seed sowing, reduction in seed rate and time for sowing, reducing thinning cost, hill dropping of the seed can be achieved with this improved system of planting. Direct sowing by Drum seeder in rows facilitated to take up fertilizer application, plant protection measures and weed control in an efficient manner. Direct sowing by Drum seeder is only a viable option to reduce cost of cultivation of paddy and increase net returns due to less seed rate, less labour for sowing, no need of nursery raising and also increased number of effective tillers. A Drum seeder is a simple manually operated implement for sowing rice seed on puddled soil (Phani and Raju 2015).

2.4 Important Factors in Direct Seeded Rice

2.4.1 Land preparation

A well-prepared and leveled field gives a uniform, healthy crop that can compete with weeds, use less water, and give higher yields at a lower cost. Proper land preparation and leveling ensure the uniform spread of water during irrigation and facilitate easy drainage when required during crop establishment. With inadequate water control and/or poor drainage, wet direct seeded rice may run the risk of early stage submergence and crop failure (Bhuiyan et al. 1995).

Land preparation operations are essentially the same for transplanted rice (TPR) and wet seeded rice (WSR). Moody (1977) reported that leveling the field is more important in WSR than in TPR as developing rice seedlings can be killed or greatly retarded in their growth when ponding of water occurs. De Datta (1986) also stated that better field leveling is necessary for seeding to achieve good water control and crop establishment and avoid poor seed germination and poor root anchorage where the water is too deep. Therefore leveling, good field drainage and good water control are essential for WSR establishment.

2.4.2 Water management in wet direct seeded rice

The absence of standing water in the initial stages encourages the emergence of weeds that compete with rice seedlings. Water management is critical in wet direct seeded rice, especially during the first 7-10 DAS. During this period, soil should be kept saturated but not flooded to facilitate root and seedling establishment (De Datta 1986; Lim et al. 1991; Awang 1995; Ho 1995; Jaafar et al. 1995; Pablico et al. 1995). For successful wet seeding, satisfactory drainage is necessary in areas subject to flooding. Proper land preparation and leveling ensure the uniform spread of water during irrigation and facilitate easy drainage when required during crop establishment (Bhuiyan et al. 1995).

Farmers generally maintain a water level of 2-5 cm throughout the crop growth period to favor rice growth and minimize weed pressure. Water stress at the reproductive stage is more damaging to the rice crop than at the vegetative phase. Therefore, the soil should not be allowed to dry excessively from tillering to late flowering. Under limited water supply, wet seeded rice is reported to be more tolerant of water shortages and hence more efficient in water use than transplanted rice (Bhuiyan et al. 1995). Sattar and Khan (1994) reported that direct wet-seeded rice required about 20% less water compared with transplanted rice.

2.4.3 Weeds in Direct Seeded Rice

A major impediment in the successful cultivation of direct seeded rice (DSR) in tropical countries is heavy infestation of weeds which often range from 50-91% (Paradkar et al. 1997) due to simultaneous emergence of weeds and crop and less availability of efficient selective herbicides for control of weeds during initial stages of crop weed competition. Weeds are a major constraint to the success of DSR in general and to dry direct seeded rice in particular (Johnson and Mortimer 2005; Singh et al. 2006; Rao et al. 2007). Research has shown that, in the absence of effective weed control options, yield losses are greater in DSR than in transplanted rice (Baltazar and De Datta, 1992; Rao et al. 2007). Weeds are more problematic in DSR than in puddled transplanting because (1) emerging DSR seedlings are less competitive with concurrently emerging weeds and (2) the initial flush of weeds is not controlled by flooding in Wet and Dry-DSR (Rao et al. 2007; Kumar et al. 2008). Moreover, cost for weed control is usually higher than TPR. High weed infestation is a major constraint for broader adoption of DSR (Rao et al. 2007).

2.4.4 Weed management strategies in direct seeded rice

Cultural practices and manual, mechanical, and chemical methods are used to manage weeds in direct-seeded rice. The selection of weed-suppressing rice varieties and use of clean seed are the basis for reducing weed pressure in any rice system. Some farmers use repeated plowing at 7-10-d intervals to uproot emerging weeds and to prepare clean seedbeds for sowing. Farmers in the Philippines and Vietnam use high seed rates to suppress weed pressure at the early stages. Labor is used to remove weeds manually in broadcast-sown or row-seeded rice and mechanical weeding with an interrow cultivator is possible only in row-seeded crops. Herbicides can be used to kill weeds wherever they are appropriate and economically attractive. Good land preparation and leveling, the selection of weed-competitive varieties, the use of clean weed-free seeds, proper water management, and intensive multiple cropping will help reduce weed pressure in wet direct seeded rice (Vongsaroj 1995).

If manual weeding is practiced, a minimum of two hand weedings at 15-20 and 30- 35 days after sowing (DAS) will be needed. Manual weeding is difficult in broadcast-sown rice because of high plant density and the problem of differentiating grassy weeds, especially *Echinochloa crusgalli, Leptochloa chinensis,* and weedy rice, from rice plants (Vongsaroj 1995). Balasubramanian and Hill (2002) expressed that if the crop is planted in rows, rotary (in sandy to sandy loam soils) or conical weeders (in clayey soils) can be used to control weeds.

Many rice farmers apply preemergence herbicides to kill weeds in the early stages and then use standing water to suppress weed growth in the later stages. During herbicide application, a thin layer of water is maintained on the soil surface to evenly spread the herbicide over the entire field. For effective weed control with herbicides, selection of the right herbicide or herbicide combination, application at the recommended rate and time, and maintenance of proper field conditions for herbicide application are vital (Balasubramanian and Hill 2002).

IRRI (2015) expressed that weeds compete directly with the rice plants and reduce rice yield. Each 1 kg dry matter of weeds is equivalent to 1 kg grain loss. Weeds cause most yield loss within the first 20-50 days after crop establishment. Weeding after panicle initiation may also be important to prevent weeds shedding seeds in future crops.

2.4.5 Rice varieties in direct seeded rice

Das (2003) reported that the production factors such as selection of variety plays an important role in enhance the productivity of rice in any location as yields differed significantly among varieties.

The characteristics of the cultivar such as morphology and growth rate can have a significant effect on crop development and ultimately its yield potential. The morphological and physiological traits of a strongly competitive crop will enable it to capture resources from weeds and utilize resources more efficiently (Lemerle et al. 2001). Correct choice of cultivar may also be essential in maintaining crop quality, contrary to complex crop management schemes, requiring specialized skills and training, improved varieties have a high potential for adoption by farmers.

IRRI (2015) expressed that the most suitable variety is the one best meeting farmer’s and consumer’s needs. It may not always give the highest yield and will be influenced by availability of water (either from rain or irrigation), soil type, and field elevation, and whether the rice will be sold or consumed at home.

Some varieties which have been specifically bred for transplanted condition perform fairly well under direct seeding. However, rice varieties must be improved for early seedling vigor, weed competitiveness, submergence tolerance to survive untimely rainfall during stand establishment, and drought tolerance to survive dry conditions during germination and later growth stages. Rice varieties selected for wet seeding must have flexible but strong stems to resist lodging at maturity. Other traits such as high yield, good grain quality, and resistance to insect pests and diseases must be retained.

Pathinayake et al. (1991) stated that improved, short-stature, erect-leaf varieties could be accommodated in WSR culture. Early maturing rice cultivars (about 100days duration) and medium duration cultivars are recommended and farmers are encouraged to used certified seeds for WSR (De Datta 1981; Awang 1995). Varieties for direct seeding should possess good seedling vigor, deep roots, and weed competitiveness. Tolerance for drought and submergence, resistance to thrips and blast are also needed. Non-lodging characteristics should be involved priority. A uniculm plant, panicle weight type variety having medium tillering habit and capacity for better stand establishment performs superior growth and grain yield under direct seeded rice (Pathinayake et al. 1991; Singh and Pilli 1996).

2.4.6 Seed rate

The published literature shows a widespread use of seed rates of up to 200 kg ha^{-1} to grow a DSR crop (Guyer and Quadranti 1985). High seed rates are used mostly in areas where seed is broadcast with an aim to suppress weeds or when water-seeded (Moody 1977). However, it is not clearly known whether a high seed rate is primarily used to control weeds or is really a requirement to raise a good crop of DSR. Studies have reported an increase in yield only in weedy plots and not in weed-free or weeded plots with increases in seed rate. Therefore, higher seedling rates can be beneficial only in conditions with no or partial weed control (Guyer and Quadranti 1985; Castin and Moody 1989). Farmers also use high seed rate when conditions for germination are poor due to damage by birds, insects, rats, etc. or the germination percent of seed itself is low. The benefits of a higher panicle number associated with a higher seed rate are offset by a reduction in panicle length and grain weight per panicle (Bhattacharjee 1978).

When using a drill for seeding, the seed rate can be decreased drastically without causing any adverse effect on yield if weeds are controlled effectively. Very few studies have been conducted evaluating the effects of seed rate to assess the performance of Dry-DSR. However, others found no difference in yield with a range of seed rates (Jones and Snyder 1987; Gravois and Helms 1992; Johnson et al. 2003; Xie et al. 2008).

High seed rates can result in large yield losses due to excessive vegetative growth before anthesis followed by a reduced rate of dry matter accumulation after anthesis (Wells and Faw 1978) and lower foliage N concentration at heading (Dingkuhn et al. 1990). These factors result in higher spikelet sterility and fewer grains per panicle (Huan et al. 1999; Tuong et al. 2000; Baloch et al. 2007; Kabir et al. 2008). Moreover, dense plant populations at high seed rates can create favorable conditions for diseases (e.g., sheath blight) (Mithrasena and Adikari 1986; Guzman and Nieto 1992) and insects (e.g. brown planthoppers) and make plants more prone to lodging (Dofing and Knight 1994; Islam et al. 2008). A high seed rate also increases establishment costs.

Plant spacing has a major effect on crop yields. Huan et al. (1999) showed that, as the seed rate increases, tillering decreases and panicle density is more dependent on primary than on secondary or tertiary tillers. Panicles from primary tillers are more productive than those from secondary and tertiary tillers, so optimal spacing should be targeted to have more panicles from primary tillers by minimizing interplant competition. Much research on plant spacing is done for optimizing transplanting (De Datta 1981).

2.5 Causes of Shifting from Transplanting to Direct Deeding

2.5.1 Water scarcity

Water availability largely determines the potential crop yield. For a crop to continue to grow, the water supply needs to be similar or a little above evaporation. In an efficient system, each 1 kg of grain produced will require a minimum of 2,000 liters or 2 m^3 of water. Good water control increases crop yields and grain quality as well as improving the efficiency of other inputs such as fertilizer, herbicide, and pesticides (IRRI 2015).

Rice is a major user of freshwater because of its large area and consumption, which are, two to three times more than other cereals (Barker et al. 1998; Tuong et al. 2005; Carriger and Valle´e 2007). Barker et al. (1998) expressed that rice consumes about 50% of total irrigation water used in Asia. Conventional rice production systems (puddled transplanting) require large quantities of water.

Globally, water is becoming an increasingly scarce resource. Increasing water scarcity has threatened the productivity and sustainability of the irrigated rice system in Asia (Tuong et al. 2004). There are two key types of water scarcity: physical and economic. Physical scarcity occurs when the demand of the population exceeds the available water resources of a region. Economic water scarcity occurs when water is adequate, but is unavailable due to a lack of significant investment in water infrastructure (IWMI 2000; Rijsberman 2006). Another evidence of growing water scarcity is the depleting groundwater resources, especially in South Asia and North China (Postel 1997; Shah et al. 2007).

2.5.2 The labor shortage and increasing labor wages

Transplanted rice is highly labor intensive. Both land preparation (puddling) and crop establishment methods (transplanting) require a large amount of labor. Rapid economic growth in Asia has increased the demand for labor in nonagricultural sectors, resulting in reduced labor availability for agriculture (Dawe 2005).

Because of increasing labor scarcity, labor wages make the puddled-transplanted rice production system uneconomical in many Asian countries. Because of high labor demand at the time of transplanting, increasing labor scarcity and rising wage rates are forcing farmers to opt for a shift in method of rice establishment from transplanting, which requires 25-50 person-days ha^{-1}, to direct seeding, which in comparison needs about 5 person-days ha^{-1} (Balasubramanian and Hill 2002; Dawe 2005).

Generally, rice growers face the problem of skilled labour shortage at the time of transplanting which results into low plant population and eventually low rice yield (Aslam et al. 2008). To overcome this problem, direct seeding of rice seems only viable alternatives in rescuing farmers (Aslam et al. 2008). This technique reduces labour needs by more than 25% in term of working hours. The input requirements and the investment in direct seeded rice are much lower than in transplanted rice (Sunil et al. 2002). If managed properly, direct seeded rice can yield as high as transplanted rice (Hayat et al. 2003; Ali et al. 2007).

2.5.3 Crop intensification and recent developments in DSR production techniques

In rice, the planting methods have an impact on the growth and yield besides cultivation cost and labor requirements (Rani and Jayakiran 2010). Although labor and water are the major drivers for the shift from transplanted rice to Direct Seeded Rice (DSR), economic incentives brought out by DSR through the integration of an additional crop (crop intensification) are another reason for the rapid spread/adoption of DSR in some regions. Asian rice farmers are shifting to direct seeding to reduce labor input, drudgery in farming, and cultivation costs (De Datta and Flinn 1986).

Wet seeding is increasingly practiced in irrigated and favorable rainfed lowlands and it has been a common practice in most developed countries because of high wages and scarcity of labor (Smith and Shaw 1996). In developing countries, direct seeding is adopted because of the migration of farm labor to nonfarm jobs and the consequent shortage of labor and high wages (Pandey 1995).

2.6 Potential Advantages and Disadvantages of Direct Seeding

2.6.1 Potential advantages of direct seeding

Direct-seeding methods have several advantages over transplanting (Singh et al. 2005). Direct seeding saves the labor. Depending on the nature of the production system, direct seeding can reduce the labor requirement by as much as 50%. Direct seeding can still be beneficial because the demand for labor is spread out over a longer time than with transplanting. Land preparation, laddering, and weeding operations in this system are spread over several months, thus allowing farmers to make full use of family labor and to avoid labor bottlenecks (Singh et al. 1994). Direct seeding may help reduce the production risk when rainfall at planting time is highly variable. Direct seeding can facilitate crop intensification. Finally, irrigation water use can be reduced if direct seeded (especially dry seeded) rice can be established earlier by using pre monsoon showers.

Direct seeding method is early flowering and shorter day maturity because it had better crop establishment, with higher intra competition due to shorter spacing and plant density per unit area, triggering quicker reproductive phase responses. Direct seeded rice matures seven to ten days earlier than transplanted rice. The longer days to flowering and maturity in seedling transplanting could be due to longer period required for crop establishments compared to direct seeded method (Rana et al. 2014).

Another potential advantage of direct seeding is the increased chance of planting another crop immediately after harvesting rice. Direct seeded rice is often planted early in the season and hence is harvested early when soil moisture is still available for another crop. Favorable areas with a high chance of double cropping may be suitable for direct seeding.

In addition to higher economic returns, DSR crops are faster and easier to plant, less labour intensive and consume less water (Jehangir et al. 2005; Bhushan et al. 2007), are conducive to mechanization (Khade et al. 1993), generally flower earlier leading to shorter crop duration (Santhi et al. 1998; Farooq et al. 2006a, b) and mature 7-10 days earlier and have less methane emissions (Pandey and Velasco 1999; Balasubramanian and Hill 2002) than TPR.

2.6.2 Potential disadvantages of direct seeding

However, direct seeding also has several potential disadvantages. The yield of direct seeded rice under farmers' field conditions tends to be lower than that of transplanted rice. Poor and uneven establishment and inadequate weed control are the major reasons for its poor performance (Moody 1982; De Datta 1986). In addition, the chemical cost of weed control tends to be higher than that of transplanted rice. More use of chemical weed control methods in direct seeded rice can also be potentially damaging to human health and the environment.

A major problem of direct seeding is poor crop establishment due to inadequate soil moisture at seeding. Another common problem is the high level of standing water at seeding time that causes poor germination. Furthermore, fields in low-lying areas or with heavy clay soils and poor drainage have a high probability of having excess moisture at seeding, and hence are risky for direct seeding (Sipaseuth et al. 2002).

2.7 Effect of Varieties and Planting Methods on Yield and Agronomic Characters of Rice

Mamun (2005) observed that Line sowing method showed better performance than broadcast method. Bari (2004) also found significantly higher grain yield from direct wet seeded Line sowing method than other methods. Darko et al. (2013) stated that crop yields in a specific area are expected to vary due to varying in weather conditions between years and within seasons.

Wells and Faw (1978) reported that high seed rate can result in large yield losses due to excessive vegetative growth before anthesis followed by a reduced rate of dry matter production after anthesis. The mean effects of increasing plant population by different planting methods, is increased competition between adjacent plants (Hay and Walker 1989) which subsequently affect yield.

Optimum spacing varies with tillering capacity and growth duration of a variety (Yoshida 1981). Phuong et al. (2005) and Chauhan et al. (2011) mentioned that increase in seed rate can cause an increase in number of tillers. Sharma (1994) who reported that as seeding rate was increase, the panicle bearing m^{-2} increased significantly.

Drum seeder planting method due to greater availability of photosynthats and less intra-plant competition, which resulted in better panicle development causing more appropriation and more number of spikelets $panicle^{-1}$. These results are supported by Aslam et al. (2002) who reported that maximum number of spikelets $panicle^{-1}$ at the lower seeding densities. Hossain et al. (1991) reported that the number of spikelets $panicle^{-1}$ was influenced by variety.

Yoshida (1981) reported that factors such as weather, soil, fertilizer application and incidence of pests affect filled spikelets or sterility percentage. Yoshida et al. (1972) reported that weather conditions, cultural management and nutrient supply greatly influence each yield component of rice. Rice grain filling and ripening are affected by many environmental factors, including water, temperature, radiation, incidence of pests and soil nutritional conditions (Yoshida 1981). Aslam et al. (2002) who reported lower percentage of normal kernels at higher seeding densities.

Ashraf et al. (1999) indicated that 1000-grain weight, an important yield determining component, is a genetic character least influenced by the environment.

Matsushima (1980) reported that the weight of 1000-grains always shows the least variation under any cultural seasons and practices, compared with other components. Among the yield components, 1000-grain weight was less influenced by the treatment combinations because it is more or less genetically controlled characteristic. It is usually a stable varietal character and the management practice has less effect on its variation (Yoshida 1981).

Sharma (2002) reported significant different in panicle length among fine grain rice genotypes. Alam et al. (2012) reported that panicle length varied significantly due to different varieties. Dingkuhn et al. (1991) indicated that the growth dynamics and partitioning patterns of rice depend on cultural practices, particularly on planting methods.

Bikash et al. (2013) also reported that harvest index (HI) differed significantly among the varieties. Harvest index may change depended on variety. Important of harvest index is due to its critical role in expressing the efficiency of grain production in crop plant. Variations in harvest index within a crop are mainly attributed to differences in crop management (Yang et al. 2000; Guo et al. 2004; Kemanian et al. 2007; D'Andrea et al. 2008; Peltonen-Sainio et al. 2008).

Grain yield is a function of interplay of various yield components such as number of productive tillers, number of spikelets panicle^{-1}, filled grain percentage and 1000 grain weight (Hassan et al. 2003). Lack (2011) also reported that yield was a function of many factors including plant growth duration, speed, duration and the association of many critical processes during the plant development. Under most conditions, spikelet number per square meter appears to be the major factor limiting rice yield. The panicle number per square meter can be varied by varying plant density and tillering performance. But beyond a certain density, correlations are negative between panicle number per square meter and spikelet number per panicle. Spikelet number per square meter is determined by the potential of a variety, the environment and nutrition. Percentage of filled spikelets of a rice crop is affected by such factors as climate, soil, variety, and nitrogen fertilization (Yoshida and Parao 1976).

2.8 Economic Impact in Direct Seeding

Economic incentives for direct seeding increase when labor scarcity and wage rates are high. Hong and Park (1992) reported that labour savings are needed to reduce rice production costs. Although the direct-seeding method has advantages and disadvantages, its rapid spread in various parts of Asia indicates that the net economic benefit has been positive. Despite a lower average yield, direct seeded rice has a higher net profit, with the savings in labor cost outweighing the value of loss in output. Park et al. (1995) observed that labour savings and cost reduction effects resulted from the adoption of direct sowing in rice cultivation in the Korea Republic. Where drought and early submergence impede the adoption of direct seeding, research to develop varieties and crop management practices to relax these constraints is also needed. The high costs of weed control could be a major constraint to the widespread adoption of direct seeding methods, especially dry seeding. Masud et al. (2014) expressed that the highest cost benefit ratio in direct seeding of sprouted seed method may be due to high yield, saving of irrigation water for puddling and labour charges bared for seedling raising and transplanting in the field. Rani and Jayakiran (2010) had found higher net return in his experiment due to saving of labour cost and irrigation water in direct seeded rice. Nagappa et al. (2002) observed that economic benefit of drum seeding and transplanting of two rice varieties at farmers' field and suggest that drum seeding would help the profitability of rice farming. Kikon and Gohain (2015) expressed that the highest cost of cultivation under broadcasting method, which was due to higher seed and cost of chemical required for seed treatment whereas the lowest cost of cultivation was incurred by all the cultivars under line sowing owing to lower requirement of seeds and chemicals.

2.9 Technological Opportunities for Sustainable Rice Production

To emphasize long-term sustainability rather than short-term productivity, the system shall reduce energy and resource use; employ production methods that restore homeostatic mechanisms conductive to community stability, optimize the rate of turnover and recycling of matter and nutrients, maximize the multiple-use capacity of the landscape and ensure an efficient energy flow; encourage local production of food items adapted to the natural and socioeconomic setting; and reduce costs and increase the efficiency and economic viability of small and medium-sized farms, there by promoting a diverse, potentially resilient agricultural system (Altieri 1987). Hence, in order to achieve sustainable rice production, it is essential to have a new orientation (e.g. reengineering of agriculture mechanization), new strategies and an unprecedented commitment from national policy makers.

Presently, the world's population continues to increase while global rice production is confronting issues such as climate change and the scarcity of water, land

and energy resources. The issues and opportunities for sustainable increase of rice production differ from one rice ecosystem to another due to differences in environmental and socio-economic conditions, degrees of intensification, and crop management operations. However, the existing, improved and promising technologies can employee to boost farmers' production and to increase their incomes, while ensuring sustainable rice production (Nguyen 2011).

Therefore, the sustainability of rice ecosystem and ability to increase production in pace with population growth with reduced water and labour use and climate changes are major concerns in conventional method of cultivation of rice. Only direct-seeded rice (DSR) is feasible alternative with good potential to save water, reduce labour requirement, mitigation of Green House Gases (GHGs) emission and adaptability to climate risks. Mostly scientists now agree that rising atmospheric concentrations of GHG threaten to have severe impacts on food production, natural ecosystem and human health (Mukteshawar and Shehrawat 2015). Chauhan (2013) found that in many Asian countries farmers are shifting from transplanting to direct seeding. Min et al. (2011) who also reported that direct seeding was an effective crop production method for reducing crop production costs and also water and soil conservation. However, Kaur et al. (2011) who reported that considering the need of more technical knowledge for the adoption of DSR technology, the government should organize training programs for skill development.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental Site

The experiments were conducted at A Lann village, Maubin Township, upper delta area under Ayeyarwaddy Region and Ka Tote Phayar Gyi village, DaikU Township, Bago (East) Region during the dry season 2016. The experimental site of Maubin Township, Ayeyarwaddy Region is located between 16º 73' N latitude and 95º 65' E longitude. It is situated at an altitude of 13.00 meter (42.90 ft) above the sea level. The experimental site of DaikU Township is located between 17º 33' N latitude and 96º 48' E longitude of 18.00 meter above the sea level.

3.1.1 Experimental design

A split plot design with three replications was assigned. The three varieties (Theehtatyin, Yeanelo 4 and Yeanelo 1) were laid down as main plot while three sowing methods (broadcasting, Line sowing and Drum seeder) were laid down as sub plot. The same experimental design was used in both locations. Individual plot size was 5 m × 4 m and it consisted of 24 rows with a spacing of 20 cm in Line sowing and Drum seeder plots. The whole experimental plot size was 864.5 m^2.

3.1.2 Soil sampling and analysis

Composite soil sample was collected from the both experimental sites before starting the experiment and was analyzed for various physiochemical properties at Laboratory of Soil and Water Science, Yezin Agricultural University. The results are shown in Table (3.1).

3.1.3 Weather data

Monthly maximum and minimum temperature and rainfall data during the experimental period were collected from and DaikU Township, Bago (East) Region and Maubin Township, Ayeyarwaddy Region (Appendix 1 and 2).

Table 3.1 Physicochemical properties of soil before experiment

Characteristics	Unit	DaikU		Maubin	
		Result	Rating	Result	Rating
pH		5.2	Moderately acid	5.5	Moderately acid
Available N	mg kg^{-1}	1.60	Medium	1.55	Medium
Available P_2O_5	mg kg^{-1}	1	Low	7	Low
Available K_2O	mg kg^{-1}	98	Low	524	High
Organic matter	%	0.47	Low	1.48	Medium
Textural type			Loam		Silty clay loam
Sand	%	45.00		1.9	
Silt	%	35.00		68.1	
Clay	%	20.00		30.0	

3.1.4 Field operations and crop management

The land was thoroughly prepared with one stroke of ploughing, and two strokes of harrowing and leveling before direct seeding. The seeds were soaked for 24 hours and incubated for another 36 hours. The incubated seeds were air-dried in the shade for about 10-15 minutes before sowing to facilitate singling or separating of seeds. The incubated seeds were sown on the leveled field directly as three sowing methods with the seed rate of 150 kg ha^{-1} for Broadcasting, 100 kg ha^{-1} for Line sowing and 50 kg ha^{-1} for Drum seeder.

In DaikU Township, systemic selected herbicide (M PAWN 30% EC) (Partilachlor 30% EC) was applied at the rate of 500 cc ha^{-1} at 3 DAS. Irrigation was done 2 times per week from 7 (DAS) to maximum tillering stage according to soil condition of the experiment of DaikU Township. At panicle initiation stage, a thin layer (2-3 cm) of water was kept on the plots. Water was removed from the plots during ripening stage. Insecticide (Cyclone 505 EC) was applied with the rate of (247 cc ha^{-1}) at 42 DAS. No major incidence of diseases and pests were observed.

In Maubin Township, systemic selected herbicide (M PAWN 30% EC) (Partilachlor 30% EC) was applied at the rate of 500 cc ha^{-1} at 3 DAS and systemic selected herbicide (M Paung Shin 32%WP) (Bensulfuron-methyl 14 % + Quinclorac 28 %) was applied at the rate of 988 g ha^{-1} at 10 DAS. Hand weeding was done at 40 DAS. Irrigation was done one time per week from 7 (DAS) to maximum tillering stage according to soil condition of the experiment of Maubin Township. At panicle initiation stage, a thin layer (2-3 cm) of water was kept on the plots. Water was removed from the plots during ripening stage. Insecticide (Cyclone 505 EC) was applied with the rate of (247 cc ha^{-1}) at 42 DAS. No major incidence of diseases and pests were observed.

3.1.5 Fertilizer application

Compound fertilizer (15:15:15) 100 kg ha^{-1} was applied at 14 day after sowing (DAS). Compound fertilizer (15:15:15) 100 kg ha^{-1} and urea 25 kg ha^{-1} were applied at 28 DAS. Urea 50 kg ha^{-1} was applied at 42 DAS. This was recommended by Soil Science Section, Soil Science, Water Utilization and Agricultural Engineering Division, Department of Agricultural Research (DAR).

3.1.6 Data collections

3.1.6.1 Data calculations

(a) Grain yield

The crops were harvested from the harvested area of 5 m^2 at maturity and then was threshed, cleaned and dried, and weight all grains harvested from each plot separately. After the grains from a plot were weighed, moisture content was determined. Grain yield were adjusted at 14 % moisture by using the following formula and converted to t ha^{-1}.

Adjusted grain weight at 14 % moisture level = A x W

Where,

A = Adjustment coefficient

W = Weight of harvested grains

$$A = \frac{100\text{-Moissture }\%}{86}$$

(Yoshida 1981)

(b) Yield components

The yield components data such as number of panicles $hill^{-1}$, number of spikelets $panicle^{-1}$, filled grain percentage and 1000-grain weight were separately analyzed from sampling area per plot.

(c) Harvest index (HI)

Harvest index was calculated from the two sampling areas per plot at harvest.

$$\text{Harvest Index} = \frac{\text{Economical yield}}{\text{Biological yield}}$$

(Gardner et al. 1985)

3.1.6.2 Agronomic characters

Seedlings emergence were measured from the two sampling areas (0.25 m^2 each) for broadcasting and the two sampling areas (0.2 m^2 each) for Line sowing per plot. The numbers of tillers were counted from the two sampling areas of each treatment at 14 DAS to heading stage. Plant height was measured twelve sample plants (four sample plants from the two sampling areas marking with sticks and four sample plants randomly) per plot at two weeks interval from 14 days after seeding to heading stage. Panicle length was measured from 10 panicles in each plot at harvest as a linear distance from the neck-node of the panicle to the tip of the spikelet. For total dry matter, all the plants from the two sampling areas were taken in each plot to measure total dry matter at harvest and then dried in oven at 80° C to measure dry weight and the dry weight was recorded.

3.1.7 Statistical analysis

The collected data was analyzed by using Statistix (version-8) software and treatment mean comparison was performed by using Least Significant Difference (LSD) at 5% level (Gomez and Gomez 1984).

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Experiment in DaikU Township, Bago (East) Region

4.1.1 Yield and yield components

4.1.1.1 Grain yield

The grain yield as affected by sowing methods and rice varieties in DaikU Township, 2016 dry season is shown in (Table 4.1). Mean effects of varieties showed significant difference of grain yield among the varieties ($Pr < 0.04$). The maximum grain yield (4.75 t ha^{-1}) was obtained from Yeanelo 1 variety which was not statistically significant with Yeanelo 4 variety (4.27 t ha^{-1}) and significantly difference with Theehtatyin variety (3.97 t ha^{-1}). Among the tested varieties, Yeanelo 1 showed the maximum grain yield (4.75 t ha^{-1}) whereas Theehtatyin showed the minimum grain yield (3.97 t ha^{-1}).

Grain yield was not significant difference among the sowing methods. There were no significant differences of mean effects of sowing methods in grain yield of tested varieties ($Pr = 0.57$) (Table 4.1). However, grain yield of Drum seeder (4.45 t ha^{-1}) showed relatively higher than that of Broadcasting (4.37 t ha^{-1}) and Line sowing (4.17 t ha^{-1}).

There was no interaction between sowing method and variety ($Pr = 0.98$) (Table 4.1). This indicates that the changes of grain yield in varieties were not influenced by different sowing methods.

Grain yield ranged from 3.87 t ha^{-1} to 4.85 t ha^{-1} (Figure 4.1). The mean effect of grain yield was not significantly different among the tested varieties for broadcasting. Yeanelo 1 gave the maximum grain yield (4.74 t ha^{-1}) whereas Theehtatyin gave the minimum grain yield (3.95 t ha^{-1}) at broadcasting. For Line sowing, there were not significant differences among the varieties on the grain yield. However the relatively higher grain yield (4.74 t ha^{-1}) was observed from Yeanelo 4 whereas the minimum yield was observed from Theehtatyin (3.95 t ha^{-1}) at Line sowing. There were not significant differences among the varieties on the grain yield for Drum seeder. The maximum grain yield was observed from that of Yeanelo 1 (4.85 t ha^{-1}) and the minimum grain yield (4.07 t ha^{-1}) was recorded from that of Theehtatyin at Drum seeder.

The result indicated that there was significant difference among the tested varieties. Although Theehtatyin gave the minimum grain yield (3.93 t ha^{-1}) was not significant difference from that of grain yield of Yeanelo 4 (4.27 t ha^{-1}), which was significant difference from that of grain yield of Yeanelo 1 (4.75 t ha^{-1}). The drought tolerance varieties (Yeanelo 1 and Yeanelo 4) obtained the maximum yield in comparison with Theehtatyin variety. Because water stress at any growth stage may reduce yield and the rice plant is most sensitive to water deficit from the reduction division stage to heading (Yoshida 1981).

In the case of sowing methods, there was no significant difference in grain yield among the sowing methods, Broadcasting (4.37 t ha^{-1}), Line sowing (4.17 t ha^{-1}), Drum seeder (4.45 t ha^{-1}). Mamun (2005) observed that Line sowing method showed better performance than broadcast method. Bari (2004) also found significantly higher grain yield from direct wet seeded Line sowing method than other methods.

In the present study, the grain yield of Drum seeder gave the similar grain yield as the grain yield of the two other methods, broadcasting and Line sowing at the tested varieties and this means that changes of grain yield in sowing methods was not influenced by the varieties. Wells and Faw (1978) reported that high seed rate can result in large yield losses due to excessive vegetative growth before anthesis followed by a reduced rate of dry matter production after anthesis. The mean effects of increasing plant population by different sowing methods, is increased competition between adjacent plants (Hay and Walker, 1989) which subsequently affect yield.

4.1.1.2 Number of panicles m^{-2}

There was significant difference of number of panicle m^{-2} among the tested rice varieties ($Pr < 0.05$) (Table 4.1). The maximum number of panicles m^{-2} resulted from Theehtatyin (597.11) which was significantly difference from Yeanelo 1 (418.22) followed by Yeanelo 4 (388.00).

There was significant difference on the number of panicles m^{-2} among the sowing methods ($Pr < 0.001$) (Table 4.1). Broadcasting (623.78) gave the higher number of panicles m^{-2} than the Line sowing (388.22) and Drum seeder (373.33).

There was no interaction on the number of panicles m^{-2} between the tested varieties and sowing methods ($Pr = 0.67$) (Table 4.1). This indicates that the changes in the number of panicles m^{-2} of the sowing methods were not influenced by the varieties.

Number of panicles m^{-2} ranged from 317.33 to 764.0 (Figure 4.2). There was significant difference among the tested varieties on the number of panicles m^{-2} at the Broadcasting. Theehtatyin gave the maximum number of panicles m^{-2} (764.0) whereas

Yeanelo 4 (515.33) gave the minimum number of panicles m^{-2} at the Broadcasting. In Line sowing, there also was also significant difference among the varieties on the number of panicles m^{-2}. The maximum number of panicles m^{-2} resulted from Theehtatyin (511.33) and the minimum number of panicles m^{-2} resulted from Yeanelo 4 (317.33) at Line sowing. There was no significant difference among the varieties on the number of panicles m^{-2} at Drum seeder. The maximum number of panicles m^{-2} observed from Theehtatyin (462.00) whereas the minimum number of panicles m^{-2} (326.67) observed from Yeanelo 1 at Drum seeder.

The result showed that there was significant difference among the tested varieties. The mean effect of the highest number of panicles m^{-2} (597.11) was observed from that of Theehtatyin, which was significant difference from that of other tested varieties. This variation in the number of panicles m^{-2} was due to genetic make-up of varieties. Similar trends were also found by Mahmud et al. (2012) who showed that rice varieties differed significantly in all growth characters especially tillers number.

In case of sowing methods, the mean values on the number of the panicles m^{-2} of the Broadcasting was the highest (623.78) among the sowing methods, the Line sowing (388.22) and Drum seeder (373.33) respectively. This variation of the number of panicles m^{-2} was due to the higher seed rate. These results are supported by Pedroso and Mariot (1986) and Sharma (1994) who reported that as seeding rate was increase, the panicle bearing m^{-2} increased significantly.

Table 4.1 Mean effects of varieties and sowing methods on yield and yield component characters of rice in DaikU

Treatment	Grain yield ($t\ ha^{-1}$)	Panicles m^{-2} (no.)	Spikelets $panicle^{-1}$ (no.)	Filled grain (%)	1000-grain weight (g)
Variety					
Theehtatyin	3.97 b	597.11 a	45.44 b	58.79 b	20.61 c
Yeanelo 4	4.27 ab	388.00 b	48.38 ab	78.27 a	25.12 a
Yeanelo 1	4.75 a	418.22 b	61.09 a	70.43 ab	23.64 b
$LSD_{0.05}$	**0.53**	**155.97**	**14.13**	**14.66**	**1.18**
Method					
Broadcasting	4.37	623.78 a	42.17 b	70.34	23.14 ab
Line sowing	4.17	388.22 b	54.59 a	67.68	22.84 b
Drum seeder	4.45	373.33 b	58.17 a	69.47	23.39 a
$LSD_{0.05}$	**0.59**	**70.79**	**6.09**	**3.79**	**0.54**
Pr>F					
Variety	0.04	0.05	0.07	0.05	<0.001
Method	0.57	<0.001	0.002	0.33	0.13
Var * Method	0.98	0.67	0.38	0.32	0.69
CV_a (%)	**9.26**	**25.81**	**20.90**	**16.19**	**3.89**
CV_b (%)	**13.28**	**14.92**	**11.47**	**5.33**	**2.26**

In each column, means having a common letter are not significantly different at 5% LSD.

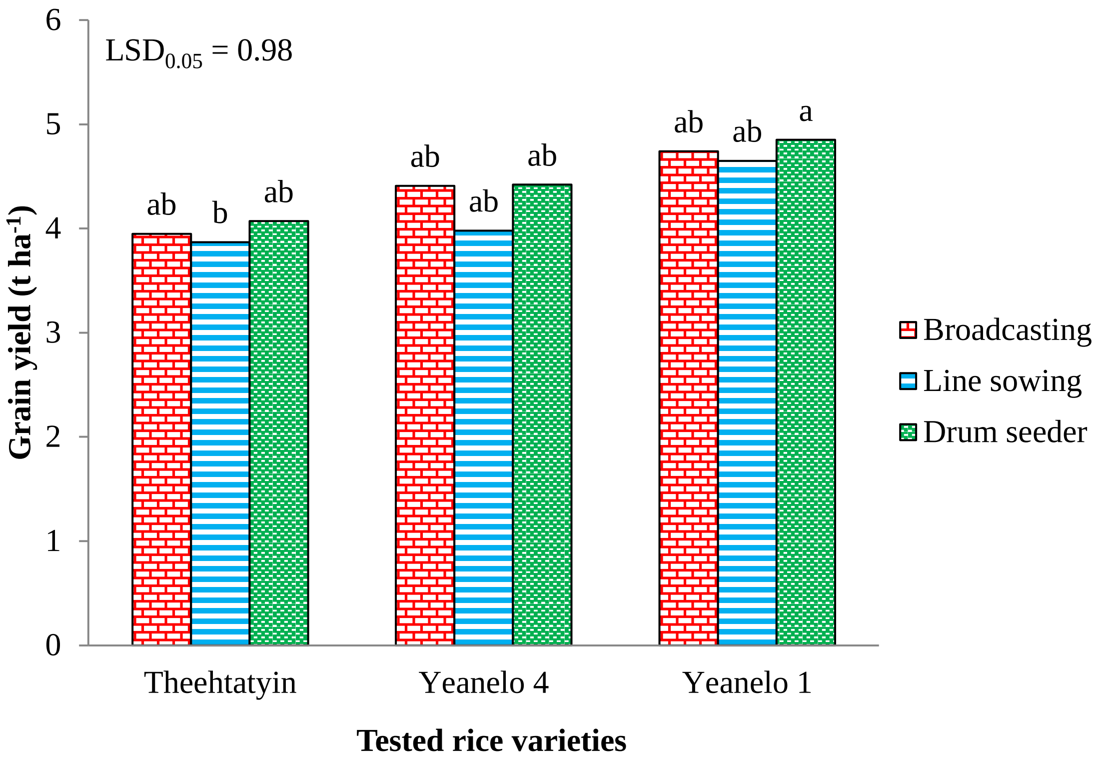

Figure 4.1 Mean comparison of grain yield (t ha^{-1}) as affected by the tested rice varieties and sowing methods in DaikU

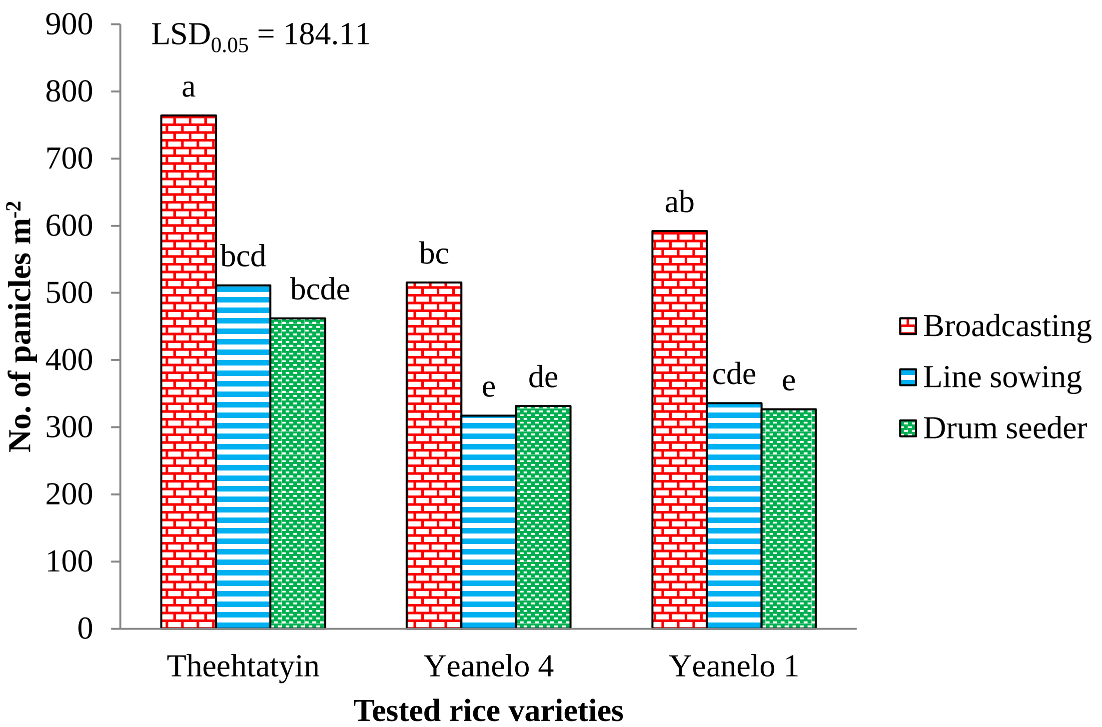

Figure 4.2 Mean comparison of the number of panicles m^{-2} as affected by the tested rice varieties and sowing methods in DaikU

4.1.1.3 Number of spikelets panicle^{-1}

Mean effect in number of spikelet panicle^{-1} among the tested varieties as affected by sowing methods was (Pr = 0.07) (Table 4.1). The maximum number of spikelets panicle^{-1} (61.09) was observed from the Yeanelo 1 and which was significantly difference from Theehtatyin variety (45.44).

There was significant difference in the number of spikelets panicle^{-1} among the sowing methods (Pr < 0.002) (Table 4.1). The mean values of the number of spikelets panicle^{-1} in Broadcasting (42.17) was relatively lower in number of spikelets panicle^{-1} than the Drum seeder (58.17) and Line sowing (54.59).

There was no interaction in the number of spikelets panicle^{-1} between the tested varieties and sowing methods (Pr = 0.38) (Table 4.1). It mentions that the changes of mean values in the number of spikelets panicle^{-1} of the varieties were not influenced by the sowing methods.

Number of spikelets panicle^{-1} ranged from (36.99) to (70.23) (Figure 4.3). Among the tested varieties, there was no significant difference in the number of spikelets panicle^{-1} at the Broadcasting. However, Yeanelo 1 gave the relatively high in number of spikelets panicle^{-1} (48.93) whereas Yeanelo 4 gave the minimum number of spikelets panicle^{-1} (36.99) at the Broadcasting. In case of the Line sowing, there was significant difference in number of spikelets panicle^{-1}. The maximum number of spikelets panicle^{-1} (64.11) resulted from that of Yeanelo 1 and the minimum number of spikelets panicle^{-1} (53.04) resulted from Theehtatyin. At the Drum seeder, significant difference in the number of spikelets panicle^{-1} was observed. The maximum number of spikelets panicle^{-1} (70.23) was given by Yeanelo 1 whereas the minimum number of spikelets panicle^{-1} (49.12) was given by Theehtatyin.

The result indicated that the maximum number of spikelets panicle^{-1} of the Yeanelo 1 (61.09) was significantly higher than the number of spikelets panicle^{-1} (45.44) of Theehtatyin and which was not significantly difference with Yeanelo 4 (48.38). This variation in the production of number of spikelets panicle^{-1} may be due to the genetic make-up of varieties. Hossain et al. (1991) reported that the number of spikelets panicle^{-1} was influenced by variety.

Regarding the sowing methods, similar mean values of the number of spikelets panicle^{-1} were observed in the Drum seeder (58.17) and Line sowing (54.59), however, which were significantly difference from the Broadcasting (42.17). Greater number of spikelets panicle^{-1} at Drum seeder sowing method was due to lower seed rate. Because of greater availability of photosynthats due to less intra-plant competition, which resulted in better panicle development causing more appropriation and more number of spikelets panicle^{-1}. These results are supported by Aslam et al. (2002) who reported that maximum number of the spikelets panicle^{-1} at the lower seeding densities.

4.1.1.4 Filled grain percentage

There was significant difference in the filled grain percent among the tested rice varieties ($Pr < 0.05$) as affected by the sowing methods is shown in (Table 4.1). Although the maximum filled grain percent (78.27) from Yeanelo 4 was similar with that of Yeanelo 1 (70.43) which was significantly difference from minimum filled grain percent (58.79) of Theehtatyin.

The data analysis of variance was not significant difference in filled grain percent among the sowing methods ($Pr = 0.33$), Broadcasting (70.34), Line sowing (67.68) and Drum seeder (69.47) respectively.

There was no interaction between the tested varieties and sowing methods in filled grain percent ($Pr = 0.32$). It explains that changes of filled grain mean values in varieties were not influenced by the sowing methods.

Filled grain percent ranged from (55.73) to (79.98) (Figure 4.4). Although the filled grain percent of Theehtatyin (60.43) was not difference from that of Yeanelo 1 (70.60), which was significant difference from the maximum filled grain percent (79.98) of Yeanelo 4 at the Broadcasting. In case of Line sowing, the minimum filled grain percent of Theehtatyin (55.73) was significantly difference from the maximum filled grain percent of Yeanelo 4 (75.21). At the Drum seeder, significant difference in filled grain percent was observed among the varieties. The maximum filled grain percent (79.63) was resulted from Yeanelo 4 whereas the minimum filled grain percent (60.21) was resulted from Theehtatyin in Drum seeder.

The result showed that the filled grain percentage of Yeanelo 4 (78.27) and Yeanelo 1 (70.43) were the maximum among the tested rice varieties at all sowing methods. Yoshida et al. (1972) reported that weather conditions, cultural management and nutrient supply greatly influence each yield component of rice. Rice grain filling and ripening are affected by many environmental factors, including water, temperature, radiation, incidence of pests and soil nutritional conditions (Yoshida 1981).

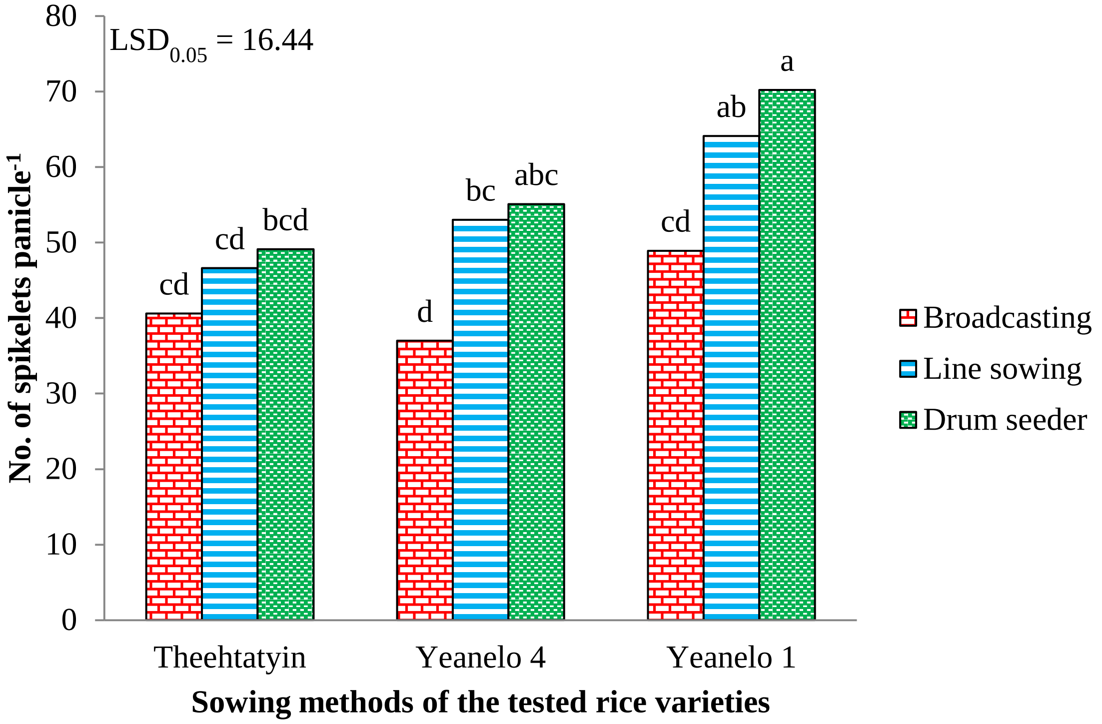

Figure 4.3 Mean comparison of the number of spikelets panicle^{-1} as affected by the tested rice varieties and sowing methods in DaikU

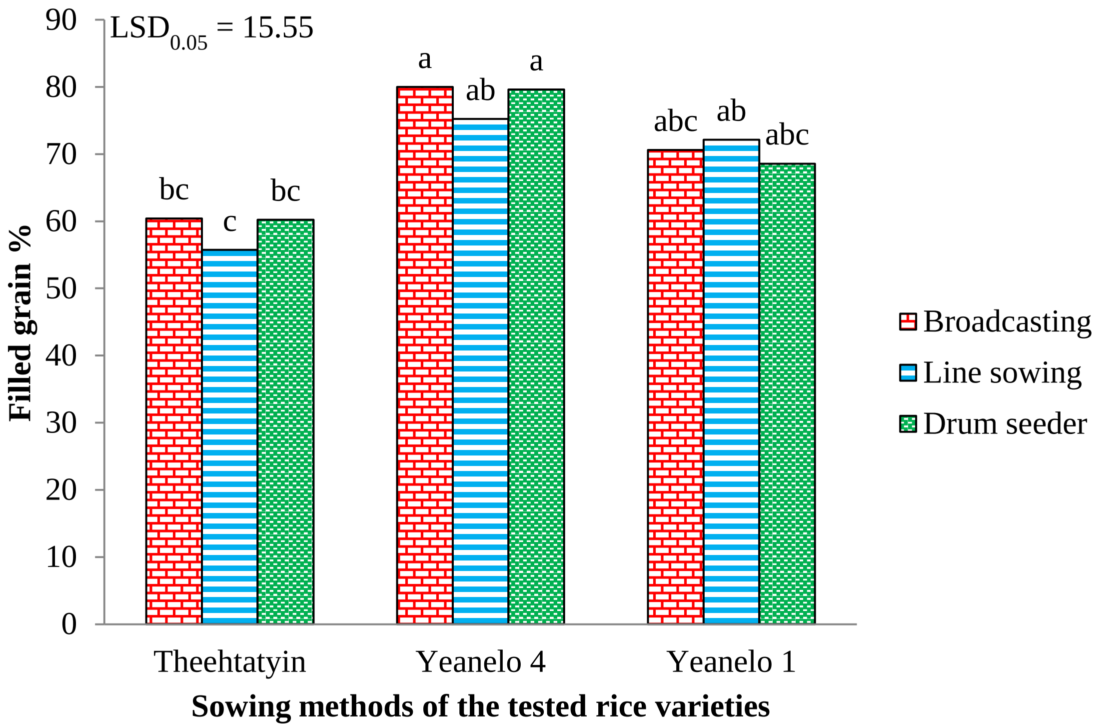

Figure 4.4 Mean comparison of the filled grain percentage as affected by the tested rice varieties and sowing methods in DaikU

4.1.1.5 Thousand grain weight

There was highly significantly difference in 1000-grain weight among the tested rice varieties (Pr < 0.001) (Table 4.1). The maximum number of 1000-grain weight (25.12 g) of Yeanelo 4 was significantly difference from Yeanelo 1 (23.64 g), and Theehtatyin which was the minimum number of 1000-grain weight (20.61 g).

Mean values of 1000-grain weight was not significantly difference (Pr = 0.13) among the sowing methods. All sowing methods showed mean values of 1000-grain weight were similarly, Line sowing (22.84 g), Broadcasting (23.14 g) and Drum seeder (23.39 g) respectively.

No interaction effect was observed in 1000-grain weight between the varieties and sowing methods (Pr = 0.69) (Table 4.1). Therefore, changes of the mean values of 1000-grain weight resulted among the varieties was no influenced by sowing methods.

1000-grain weight was ranged from (20.03 g) from (25.37 g) (Figure 4.5). Significant difference of 1000-grain weight was observed at the broadcasting. The maximum number of 1000-grain weight (25.06 g) was observed from that of Yeanelo 4 followed by Yeanelo 1 (23.57 g). The minimum number of 1000-grain weight was observed from Theehtatyin (20.77 g) at Broadcasting. In case of Line sowing, the maximum number of 1000-grain weight was resulted from Yeanelo 4 (24.94 g) and the minimum number of 1000-grain weight was resulted from the Theehtatyin (20.03 g). At the Drum seeder, significant difference of 1000-grain weight was observed. Yeanelo 4 gave the maximum number of 1000-grain weight (25.37 g) and the minimum number of 1000-grain weight (21.03g) was from Theehtatyin.

The observed result indicated that Yeanelo 4 resulted the highest number of 1000-grain weight (25.12 g) which was significantly difference from Theehtatyin resulted the lowest number of 1000-grain weight (20.61 g) in the tested rice varieties. This variation may be due to the varietal character of tested varieties.

The result indicated that significant difference was not observed in 1000-grain weight at all the sowing methods. The 1000-grain weight is a stable varietal character because the grain size is rigidly controlled by the size of the hull. Matsushima (1980) reported that the weight of 1000-grain always shows the least variation under any cultural seasons and practices, compared with other components. Among the yield components, 1000-grain weight was less influenced by the treatment combinations because it is more or less genetically controlled characteristic.

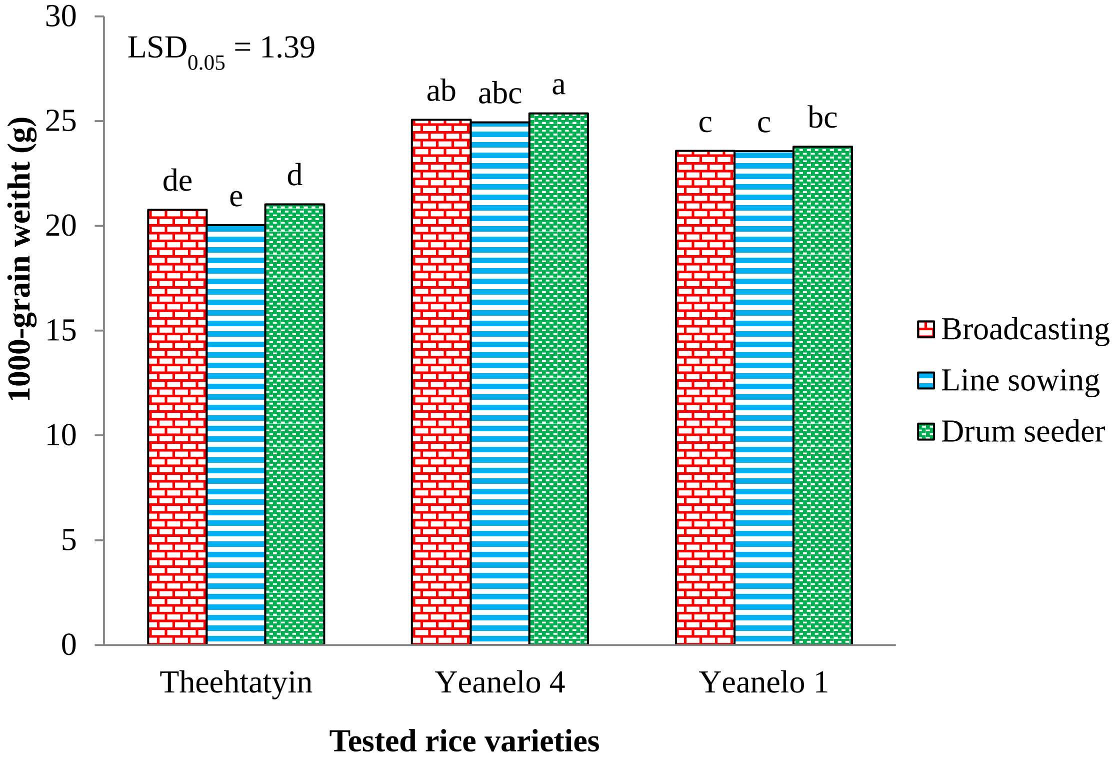

Figure 4.5 Mean comparison of the 1000-grain weight as affected by the tested rice varieties and sowing methods in DaikU

4.1.2 Agronomic characters

4.1.2.1 Number of seedlings m^{-2}

The variation of number of seedlings m^{-2} of tested rice varieties due to different sowing methods is described in (Figure 4.6). Number of seedlings m^{-2} was recorded at 14 days after sowing (DAS). According to the results, Theehtatyin produced the maximum number of seedlings m^{-2} (473.78) whereas Yeanelo 1 gave the minimum number of seedlings m^{-2} (344.44) at 14 DAS. This differences was due to genetic character of variety especially seed size.

In the sowing methods, the maximum number of seedlings m^{-2} (679.56) was observed from Broadcasting and the minimum number of seedlings m^{-2} (168.00) was observed from the Drum seeder, and followed by Line sowing, (325.56). This variation in the number of seedlings m^{-2} was due to initial seeding density of the varieties. Rice cultivars were sown using high seed rate which ultimately resulted in higher number of seedlings per unit area. Ahmed et al. (2014) expressed that rice plant density increased linearly with increase in seed rates.

There was no interaction between the tested rice varieties and sowing methods at 14 DAS, (Pr = 0.13). This means that changes of number of seedlings m^{-2} in tested rice varieties was not influenced by the different sowing methods.

Number of seedlings m^{-2} ranged from (146.00) to (859.33) (Figure 4.6). The mean effect of number of seedlings m^{-2} was significantly different among the tested rice varieties at the Broadcasting. The maximum number of seedlings m^{-2} (895.33) was resulted from Theehtatyin whereas the minimum number of seedlings m^{-2} (577.33) was resulted from Yeanelo 4 at Broadcasting. At Line sowing, there was no significant difference among the tested varieties in the number of seedlings m^{-2}. Theehtatyin gave the maximum number of seedlings m^{-2} (360.00) and Yeanelo 1 gave the minimum number of seedlings m^{-2} (275.33) in Line sowing. In case of Drum seeder, the maximum number of seedlings m^{-2} (202.00) was resulted from Theehtatyin and the minimum number of seedlings m^{-2} (146.00) was resulted from Yeanelo 4. There was no significant difference among the tested varieties under the Drum seeder.

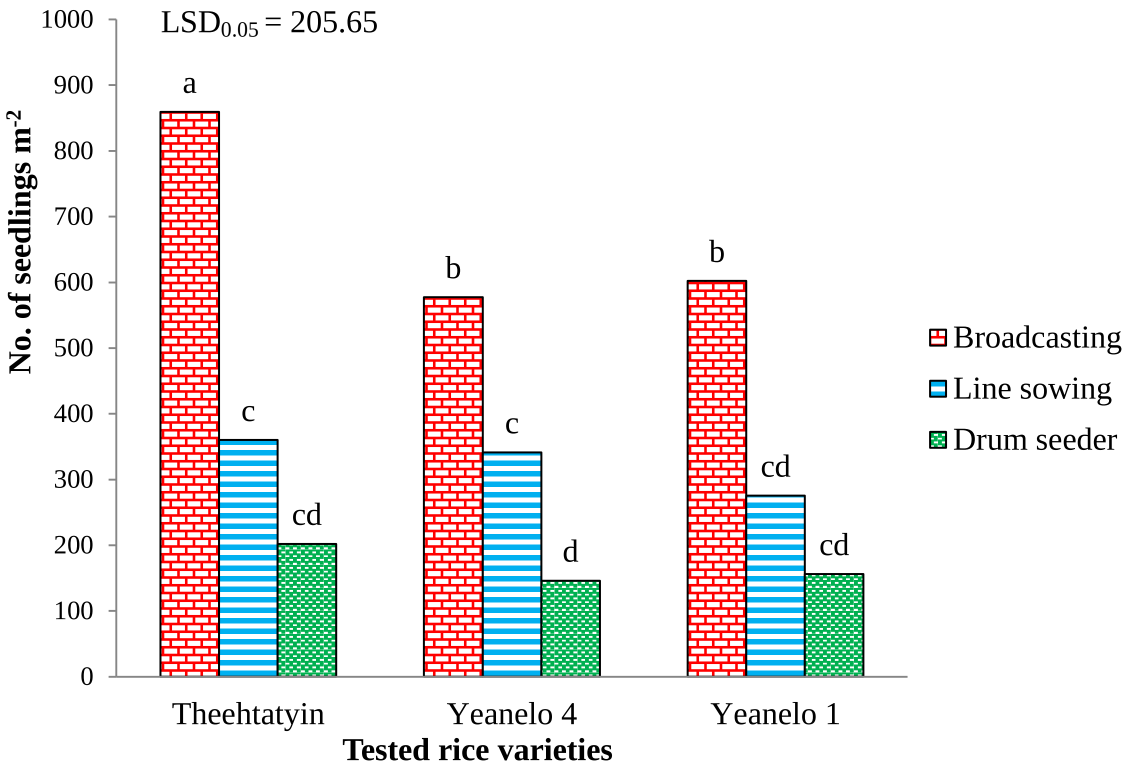

Figure 4.6 Mean comparison of the number of seedlings m^{-2} at 14 DAS as affected by the tested rice varieties and sowing methods in DaikU

4.1.2.2 Plant height

The mean value of plant height of tested rice varieties as affected by sowing methods at different growth stages in DaikU are presented in (Figure 4.7). The plant height of all varieties gradually increased until 84 DAS under different sowing methods. The highest plant height was obtained from Line sowing for all tested rice varieties except Theehtatyin, at which the highest plant height was observed from Broadcasting.

There was no significant difference in plant height among the tested rice varieties as affected by the sowing methods (Table 4.2). At 84 DAS, the maximum plant height (73.09 cm) was obtained from Yeanelo 4 followed by Yeanelo 1 (70.77 cm), Theehtatyin (59.85cm) which were not significant difference among the rice varieties.

There was no significantly difference among the sowing methods (Table 4.2). At 84 DAS, the mean values of plant height were Broadcasting (68.26 cm), Line sowing (68.86 cm) and Drum seeder (66.59 cm).

Significant interaction was not observed in plant height between the tested rice varieties and sowing methods (Table 4.2). It explains that mean values of plant height in varieties were not influenced by the sowing methods.

The combined effect of tested rice varieties and sowing methods at 84 DAS showed in (Figure 4.8). The maximum plant height was recorded from Yeanelo 4 and the minimum plant height was found from Theehtatyin among the tested rice varieties. In this study, Line sowing gave the maximum plant height among the tested varieties except Theehtatyin. It means that Line sowing had optimum line spacing which less competition for limited resource among the plants. Besides, it was due to reduce seed rate which leading to reduce competition among the plants. These was agreed with Nwokwu et al (2016) who expressed that sowing rice at 40 kg ha^{-1} seed rate produced taller plants than 80 and 120 kg ha^{-1} while the shortest plants were observed with 120 kg ha^{-1} seed rate though statistically similar with 80 kg ha^{-1}. However, the highest plant height for Theehtatyin was from Broadcasting. It was due to competition for space which might have elongated the densely populated plants. Mirza et al. (2009) reported that the plant tended to be taller for getting the light in closed place. Height of the crop is mainly controlled by the genetic makeup of the variety and can also be affected by the environmental factors and Shahzad et al. (2007) reported that plant height differed significantly by sowing time and location. Plant heights of tested rice varieties were not influenced by sowing methods in this experiment.

Table 4.2 Mean effects of tested rice varieties and sowing methods on plant height of rice in DaikU

Treatment	Plant height (cm)					
	14 DAS	**28 DAS**	**42 DAS**	**56 DAS**	**70 DAS**	**84 DAS**
Variety						
Theehtatyin	11.58	21.12	28.24	36.77	54.84 b	59.85
Yeanelo 4	11.33	22.01	31.38	43.51	62.71 a	73.09
Yeanelo 1	10.19	21.20	30.13	41.05	62.87 a	70.77
$LSD_{0.05}$	**1.53**	**4.14**	**3.71**	**6.85**	**7.29**	**14.18**
Method						
Broadcasting	10.94	21.32	28.93	39.38	59.62	68.26
Line sowing	11.23	21.72	30.25	40.71	60.23	68.86
Drum seeder	10.94	21.29	30.57	41.23	60.57	66.59
$LSD_{0.05}$	**1.18**	**1.85**	**1.87**	**2.69**	**2.42**	**4.52**
Pr>F						
Variety	0.13	0.81	0.17	0.12	0.06	0.12
Method	0.83	0.85	0.17	0.34	0.69	0.54
Var * Method	0.76	0.37	0.65	0.99	0.64	0.69
CV_a (%)	**10.59**	**14.74**	**9.48**	**12.94**	**9.26**	**15.96**
CV_b (%)	**10.39**	**8.41**	**6.10**	**6.47**	**3.92**	**6.47**

In each column, means having a common letter are not significantly different at 5% LSD

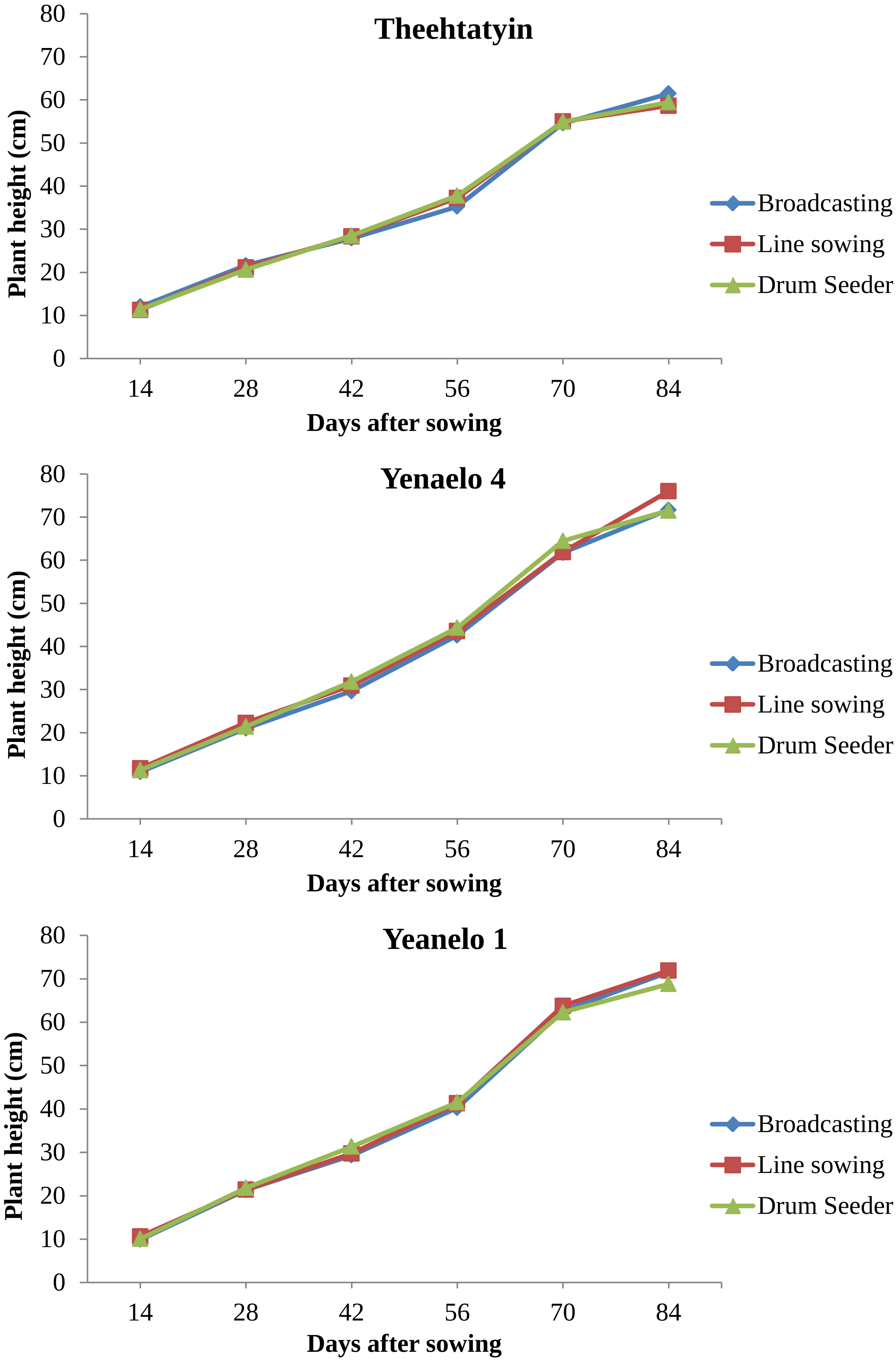

Figure 4.7 Plant height as affected by tested rice varieties and sowing methods in DaikU

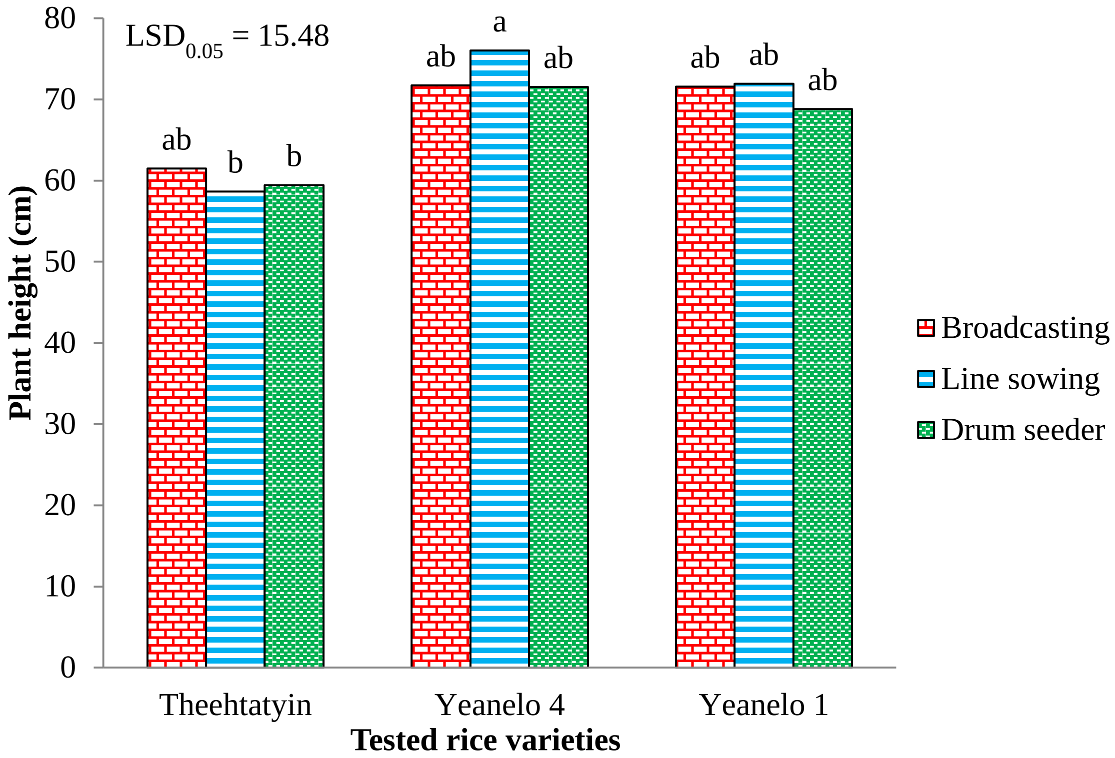

Figure 4.8 Mean comparison of plant height at 84 DAS as affected varieties and sowing methods in DaikU

4.1.2.3 Number of productive tillers m^{-2}

Number of productive tillers m^{-2} was recorded at weekly interval from 14 days after sowing (DAS) to 84 DAS. Numbers of productive tillers m^{-2} as affected by rice varieties and sowing methods at different growth stages in dry season, 2016 are shown in (Figure 4.9). The maximum number of productive tillers was obtained at 56 DAS under different sowing methods. Tillering is an important trait for grain production and is thereby an important aspect in rice yield. According to the results, the number of productive tillers m^{-2} was significant difference at all growth stages among the tested rice varieties (Table 4.3). Theehtatyin produced the maximum number of productive tillers m^{-2} whereas Yeanelo 4 gave the minimum number of productive tillers m^{-2} through the experiment. This differences was due to genetic character of variety especially seed size.

In the sowing methods, there was highly significantly difference in the number of productive tillers m^{-2} at all growth stages (Table 4.3). In this experiment, the maximum number of tillers m^{-2} was observed from Broadcasting and the minimum number of productive tillers m^{-2} was observed from Drum seeder at all growth stages.

There was interaction between the tested rice varieties and sowing methods at 84 DAS at (Pr = 0.03) (Table 4.3). This means that changes of number of productive tillers m^{-2} in tested rice varieties was influenced by the different sowing methods.

At 84 DAS, the differences of mean effect of varieties were observed in number of productive tillers m^{-2} at (Pr = 0.01) (Table 4.3). Although Theehtatyin, the maximum number of productive tillers m^{-2} (945.78), was significantly different from that of Yeanelo 4 (679.33), Yeanelo 1 (739.78)

Number of productive tillers m^{-2} ranged from (594.0) to (1385.3) (Figure 4.10). The mean effect of number of productive tillers m^{-2} was significantly different among the tested rice varieties at the Broadcasting. The maximum number of productive tillers m^{-2} (1385.3) was resulted from Theehtatyin whereas the minimum number of productive tillers m^{-2} (848.0) was resulted from Yeanelo 4 at Broadcasting. At Line sowing, there was no significant difference among the tested varieties in the number of productive tillers m^{-2}. Theehtatyin gave the maximum number of productive tillers m^{-2} (708.0) and Yeanelo 4 gave the minimum number of productive tillers m^{-2} (594.0) in Line sowing. In case of Drum seeder, the maximum number of productive tillers m^{-2} (744.0) was resulted from Theehtatyin and the minimum number of productive tillers m^{-2} (594.7) was resulted from Yeanelo 1. There was no significant difference among the tested varieties under the Drum seeder.

The result indicated that number of productive tillers m^{-2} was not significantly different among the tested rice varieties except Theehtatyin, which was the highest number of productive tillers m^{-2} (945.78). This variation in the number of productive tillers m^{-2} among the tested rice varieties was due to genetic make-up of varieties. Regarding the sowing methods, Broadcasting showed the highest number of productive tillers m^{-2} (1078.00) among the other sowing methods, Line sowing (642.00) and Drum seeder (644.00). This variation in the number of productive tillers m^{-2} was due to initial seeding density of the varieties. Rice cultivars were sown using high seed rate which ultimately resulted in higher number of productive tillers per unit area. Phuong et al. (2005) and Chauhan et al. (2011) mentioned that increase in seed rate can cause an increase in number of productive tillers. Result of present experiment indicated that Broadcasting and Drum seeder gave the maximum and minimum number of productive tillers m^{-2} at all tested varieties and this means that changes of number of productive tillers m^{-2} in Broadcasting and Drum seeder were not influenced by tested varieties.

Table 4.3 Mean effects of varieties and sowing methods on number of tillers m^{-2} in DaikU

Treatment	Number of tillers m^{-2}					
	14 DAS	28 DAS	42 DAS	56 DAS	70 DAS	84 DAS
Variety						
Theehtatyin	473.78	874.00 a	1042.40 a	1506.00 a	1292.40 a	945.78 a
Yeanelo 4	354.89	479.11 b	681.30 b	949.60 b	827.80 b	679.33 b
Yeanelo 1	344.44	518.89 b	713.60 b	1151.80 b	1016.20 ab	739.78 b
$LSD_{0.05}$	**161.98**	**237.10**	**137.56**	**282.55**	**321.62**	**136.51**
Method						
Broadcasting	679.56 a	1010.00 a	1205.10 a	1636.40 a	1384.40 a	1078.00 a
Line sowing	325.56 b	539.60 b	709.30 b	1128.40 b	968.20 b	642.00 b
Drum seeder	168.00 c	322.40 c	522.90 c	842.40 c	783.80 b	644.90 b
$LSD_{0.05}$	**91.30**	**122.09**	**101.83**	**151.89**	**190.36**	**111.27**
Pr>F						
Variety	0.16	0.02	0.003	0.01	0.04	0.01
Method	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Var * Method	0.13	0.19	0.58	0.08	0.58	0.03
CV_a (%)	**31.65**	**29.03**	**12.94**	**17.95**	**23.50**	**13.23**
CV_b (%)	**22.73**	**19.05**	**12.20**	**12.30**	**17.73**	**13.74**

In each column, means having a common letter are not significantly different at 5% LSD.

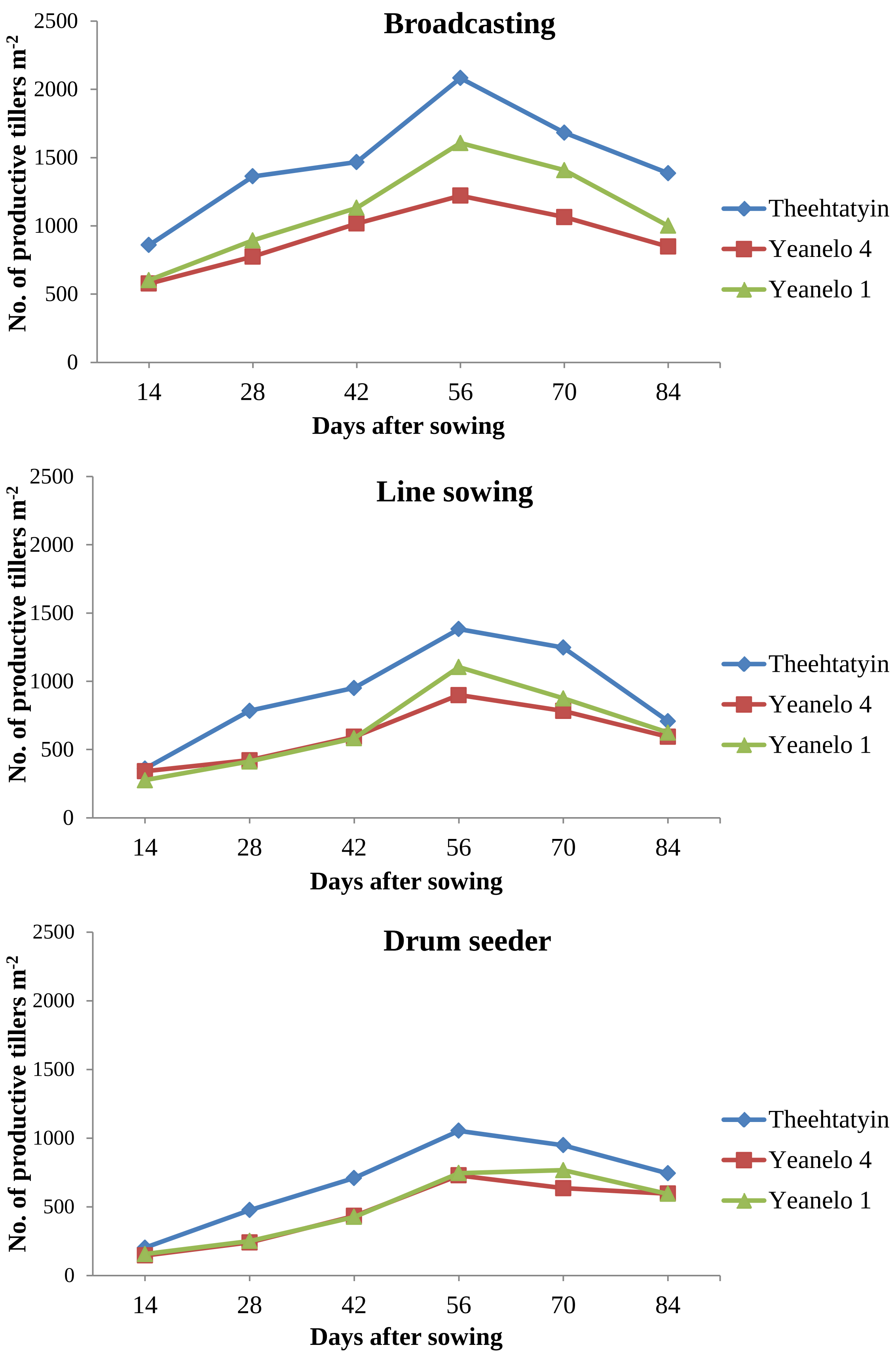

Figure 4.9 Number of productive tillers m^{-2} as affected by varieties and sowing methods in DaikU

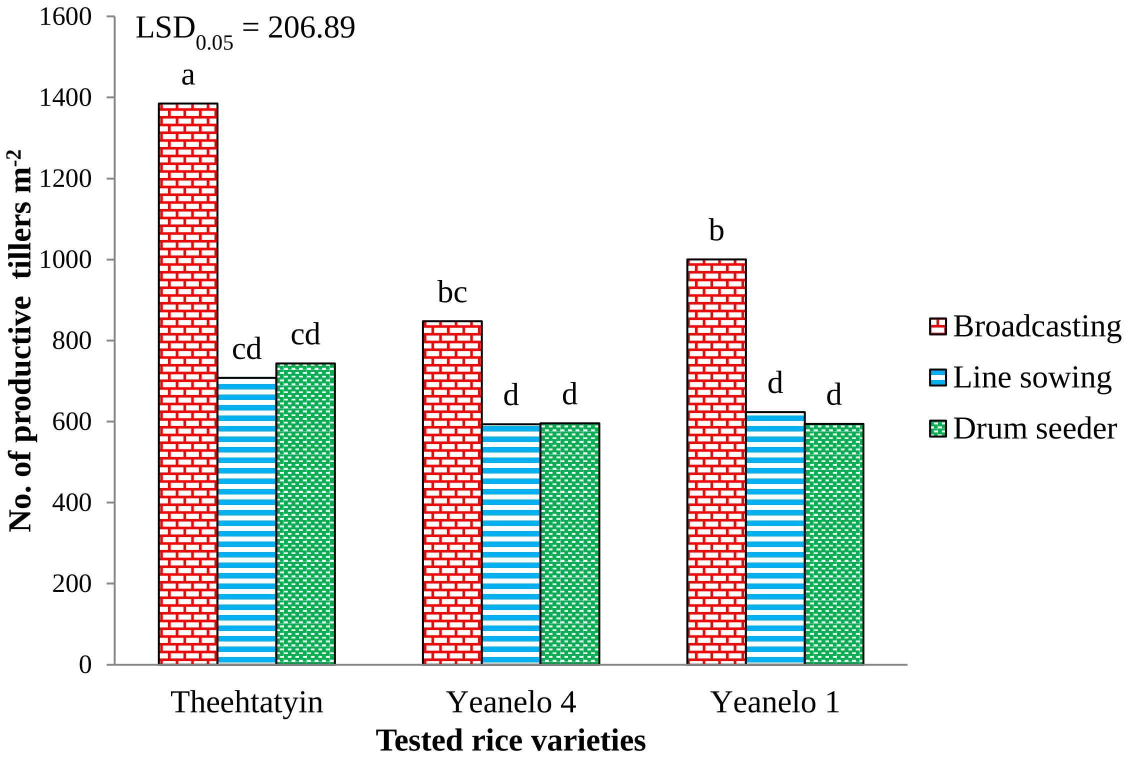

Figure 4.10 Mean comparison of the number of productive tillers m^{-2} at 84 DAS as affected by the tested rice varieties and sowing methods in DaikU

4.1.2.4 Panicle length

The differences of mean effect in panicle length of the tested varieties as affected by sowing methods are shown (Table 4.4). There was no significant difference in panicle length in varieties except Theehtatyin produced the shortest panicle length (17.37 cm). The longer panicle length (21.53 cm) was produced from Yeanelo 4 followed by Yeanelo 1 (20.67 cm). The ANOVA result indicated significant difference among the tested rice varieties ($Pr < 0.005$).

Significant difference of panicle length among the sowing methods was observed (Table 4.4). Drum seeder resulted the maximum panicle length (20.44cm) which was significantly difference from the Broadcasting (19.29 cm) and was not significantly difference from Line sowing (19.84 cm). According to ANOVA result, there was significant difference in panicle length among the sowing methods ($Pr < 0.02$).

Three was no interaction in panicle length between the tested varieties and sowing methods ($Pr = 0.45$) (Table 4.4). It means that changes of mean effect of panicle length in varieties were not influenced by the sowing methods.

Panicle length ranged from (17.02 cm) to (22.45 cm) (Figure 4.11). Mean value of panicle length in varieties was significant difference at Broadcasting. The longest panicle length (21.08 cm) was resulted from Yeanelo 4 whereas the shortest panicle length (17.02 cm) from Theehtatyin in Broadcasting. In case of Line sowing, there was no significant difference in panicle length among the varieties except Theehtatyin (17.35 cm). The longest panicle length (21.10 cm) was from the Yeanelo 1 whereas the shortest panicle length (17.35 cm) was from Theehtatyin.

The result indicated that the shortest panicle length (17.37cm) was produced only from Theehtatyin and the panicle length of other varieties was not statistically difference. Sharma (2002) reported significant different in panicle length among fine grain rice genotypes.

In the sowing methods, only Drum seeder produced the longest panicle length (20.44 cm) than the two other sowing methods, Line sowing (19.84 cm) and Broadcasting (19.29 cm). There was statistically difference in panicle length among the sowing methods.

4.1.2.5 Harvest index (HI)

Mean differences of harvest index of the tested varieties as affected sowing methods are shown (Table 4.4). Theehtatyin, the maximum number of harvest index

(0.48), was higher than the Yeanelo 1 (0.46) and which was significantly difference from Yeanelo 4 (0.44). The ANOVA showed that there was significant difference in harvest index among the tested varieties (Pr < 0.04).

Harvest index was significantly difference among the sowing methods as the ANOVA result (Pr < 0.001). The maximum number of harvest index (0.49) from Drum seeder was higher than the Broadcasting (0.44) and Line sowing (0.46).

Interaction was observed between the varieties and sowing methods in case of harvest index. It indicated that change of mean effect in varieties was influenced by sowing methods (Pr < 0.01).

Harvest index ranged from (0.41) to (0.50) (Figure 4.12). There was no significant difference in harvest index among the tested varieties except Theehtatyin which was highest harvest index (0.49) and Yeanelo 4 was the lowest harvest index (0.41) at Broadcasting. In the Line sowing, maximum harvest index (0.46) was observed from Theehtatyin and followed by Yeanelo 1 (0.46) and Yeanelo 4 (0.45). At the Drum seeder, significant difference was not observed among the varieties. The maximum harvest index (0.50) was resulted from Theehtatyin whereas the minimum harvest index (0.72) was resulted from Yeanelo 4 at Drum seeder.

The result indicated that the harvest index of Yeanelo 1 (0.46) was no significantly difference from the maximum harvest index (0.48) of Theehtatyin and the minimum harvest index (0.44) of Yeanelo 4. This result indicated that harvest index may change depended on variety. Important of harvest index is due to its critical role in expressing the efficiency of grain production in crop plant.

In the sowing methods, result showed that although the maximum harvest index (0.49) of Drum seeder was significantly higher than the other two methods, harvest index of the Broadcasting (0.44) and Line sowing (0.46) were exactly similar each other. Variations in harvest index within a crop are mainly attributed to differences in crop management (Yang et al. 2000; Guo et al. 2004; Kemanian et al. 2007; D’Andrea et al. 2008; Peltonen-Sainio et al. 2008).

Table 4.4 Mean effects of varieties and sowing methods on agronomic characters of rice in DaikU

Treatment	Panicle length (cm)	Harvest index	Total Dry Matter (t ha^{-1})
Variety			
Theehtatyin	17.37 b	0.48 a	7.63
Yeanelo 4	21.53 a	0.44 b	8.34
Yeanelo 1	20.67 a	0.46 ab	9.63
LSD$_{0.05}$	**1.72**	**0.03**	**2.01**
Method			
Broadcasting	19.29 b	0.44 c	10.38 a
Line sowing	19.84 ab	0.46 b	7.67 b
Drum seeder	20.44 a	0.49 a	7.55 b
LSD$_{0.05}$	**0.77**	**0.02**	**0.91**
Pr>F			
Variety	0.005	0.04	0.11
Method	0.02	<0.001	<0.001
Var * Method	0.45	0.01	0.18
CV $_a$ (%)	**6.64**	**4.63**	**18.03**
CV $_b$ (%)	**3.76**	**3.52**	**10.39**

In each column, means having a common letter are not significantly different at 5% LSD.

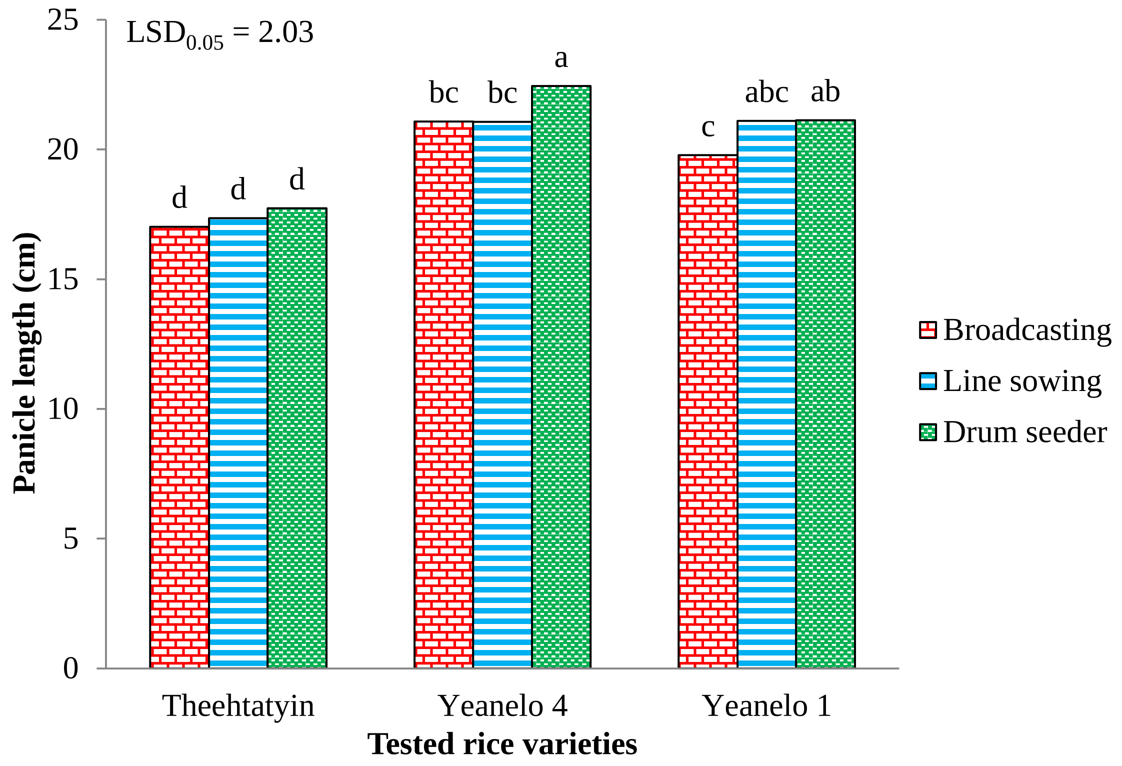

Figure 4.11 Mean comparison of the panicle length as affected by the tested rice varieties and sowing methods in DaikU

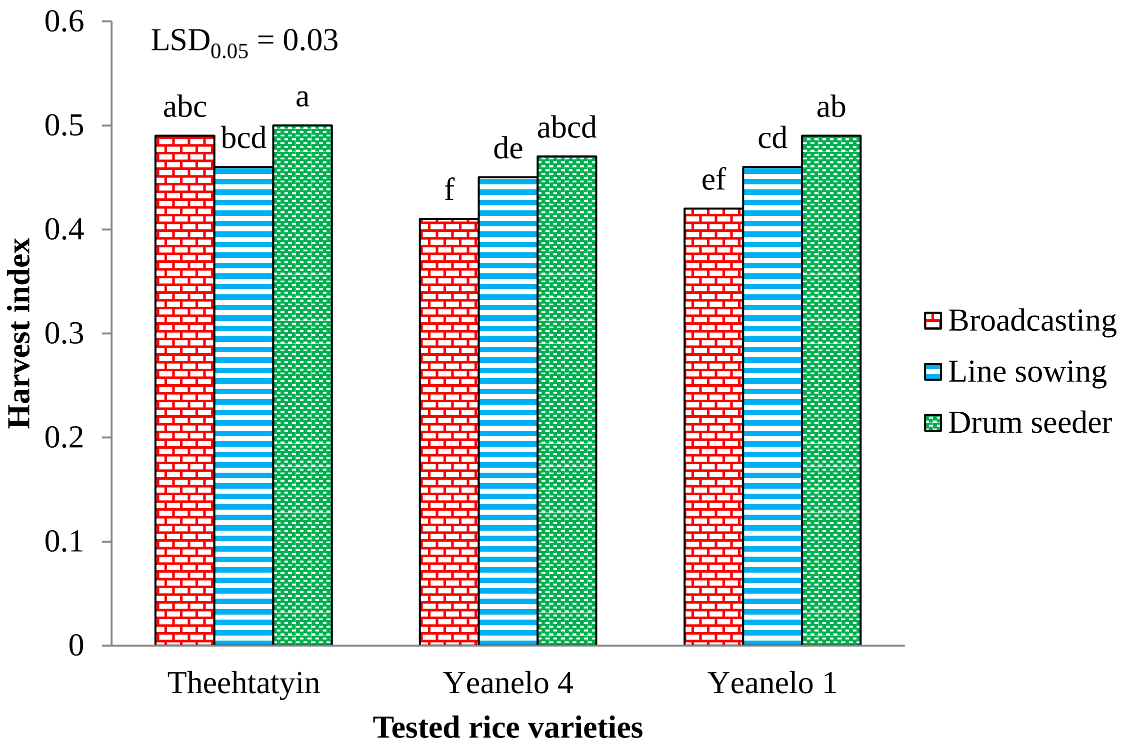

Figure 4.12 Mean comparison of the harvest index as affected by the tested rice varieties and sowing methods in DaikU

4.1.2.6 Total dry matter

Mean differences of Total dry matter of the tested varieties as affected sowing methods are shown at (Pr = 0.11) in (Table 4.4). Although the maximum total dry matter (9.63 t ha^{-1}) of Yeanelo 1 was significantly difference from the minimum total dry matter (7.63 t ha^{-1}) of Theehtatyin, which was not significantly difference from Yeanelo 4 (8.34 t ha^{-1}).

Total dry matter was highly significantly difference among the sowing methods as the ANOVA result (Pr < 0.001). The maximum number of total dry matter (10.38 t ha^{-1}) from Broadcasting which was significantly difference from Drum seeder (7.55 t ha^{-1}) and Line sowing (7.67 t ha^{-1}).

Interaction was not observed between the varieties and sowing methods in case of total dry matter at (Pr = 0.18). It indicated that change of mean effect in varieties was not influenced by sowing methods.

Total dry matter was ranged from (6.57 t ha^{-1}) to (12.22 t ha^{-1}) (Figure 4.13). The maximum total dry matter (12.22 t ha^{-1}) was obtained from Yeanelo 1 whereas the minimum total dry matter (9.35 t ha^{-1}) was observed from Theehtatyin at Broadcasting. In the Line sowing, maximum total dry matter was (8.44 t ha^{-1}) from Yeanelo 1 which was significantly difference from minimum total dry matter (6.96 t ha^{-1}) of Theehtatyin. At the Drum seeder, Yeanelo 4 gave the maximum total dry matter (8.20 t ha^{-1}) and Theehtatyin produced the minimum total dry matter (6.57 t ha^{-1}).

The result indicated that although the maximum total dry matter (9.63 t ha^{-1}) of Yeanelo 1 was not significantly difference from Theehtatyin (7.63 t ha^{-1}) and Yeanelo 4 (8.34 t ha^{-1}). This result indicated that total dry matter may change depended on variety. The variation in TDM was found due to the variation of genetic makeup of rice varieties and also the variation in plant height, tillers and leaves number $plant^{-1}$. Reddy and Reddy (1994) observed that dry matter production and grain yields were positively and significantly associated with each other.

In the sowing methods, result showed that the maximum total dry matter (10.38 t ha^{-1}) of Broadcasting was significantly higher than the other two methods, Line sowing (7.67 t ha^{-1}) and Drum seeder (7.55 t ha^{-1}). This result showed that total dry matter was increase due to increase in plant population per square meter. Lu et al. (2004) reported that dense spacing increased the dry matter production of rice.

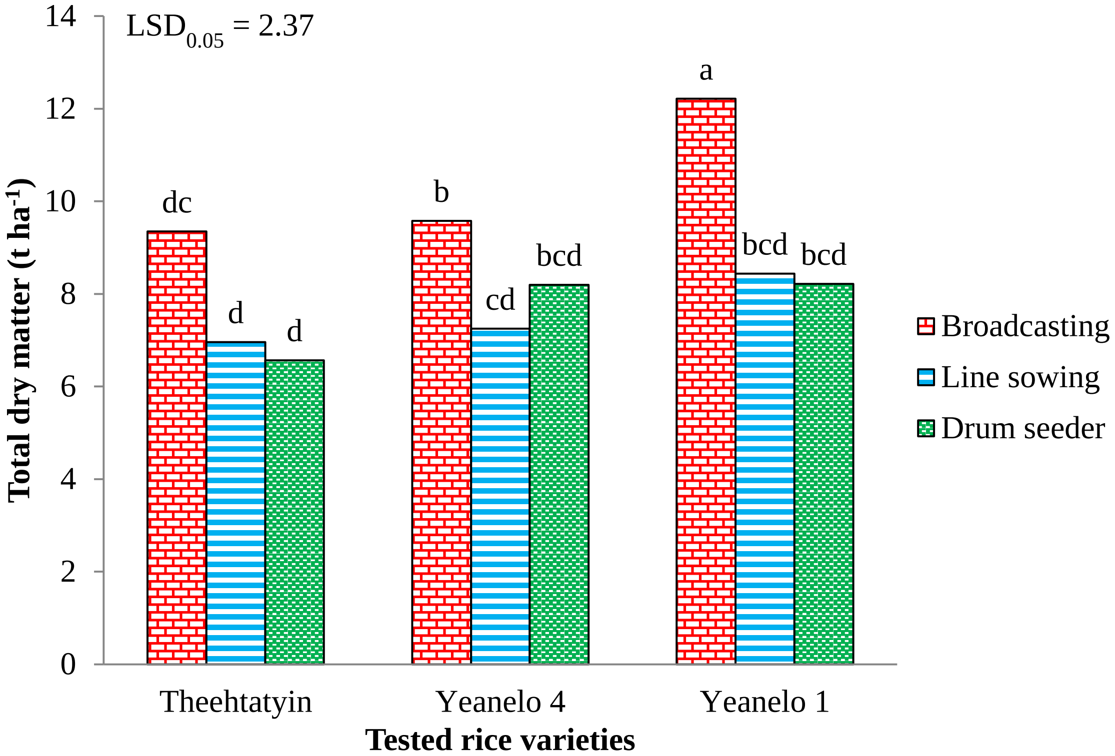

Figure 4.13 Mean comparison of total dry matter as affected by the tested rice varieties and sowing methods in DaikU

4.1.3 Correlation between agronomic characters, grain yield and yield components of tested rice varieties in DaikU

Correlation between agronomic characters, yield and yield components of the tested rice varieties in DaikU Township, Bago (East) Region during dry season, 2016 is shown in (Table 4.5). The number of panicles m^{-2} was negatively correlated with the number of spikelets $panicle^{-1}$ and panicle length at 5% significant level. Filled grain percent highly positively correlated with 1000-grain weight and panicle length at 1% significant level. 1000-grain weight was highly positively correlated with panicle length at 1% significant level.

Table 4.5 Correlation between agronomic characters, yield and yield components as affected by tested rice varieties and sowing methods in DaikU

	Number of panicles m^{-2}	Filled grain (%)	HI	Panicle length (cm)	TDM (t ha^{-1})	Number of spikelets $panicle^{-1}$	1000-grain weight (g)	Yield (t ha^{-1})
Number of panicles m^{-2}	1							
Filled grain (%)	-0.4762	1						
HI	-0.0544	-0.5547	1					
Panicle length (cm)	-0.7289 *	0.9194 **	-0.3724	1				
TDM (t ha^{-1})	0.4714	0.3079	-0.5889	0.1425	1			
Number of spikelets $panicle^{-1}$	-0.7358*	0.1285	0.3558	0.4845	-0.2163	1		
1000-grain weight (g)	-0.5708	0.9795 **	-0.4979	0.9549 **	0.2698	0.2652	1	
Yield (t ha^{-1})	-0.3363	0.4906	-0.2308	0.6296	0.5373	0.5881	0.5426	1

* Significant different at 5% level, ** significant different at 1% level.

4.2 The Experiment in Maubin Township, Ayeyarwaddy Region

4.2.1 Yield and yield components

4.2.1.1 Grain yield

Grain yield of tested rice varieties as affected by different sowing methods are shown in (Table 4.6). There were significant differences among the rice varieties at ($Pr < 0.03$). The grain yield of rice ranged from (5.23 t ha^{-1}) to (6.32 t ha^{-1}). The maximum grain yield (6.32 t ha^{-1}) was observed from Theehtatyin variety which was significantly different from Yeanelo 1 (5.42 t ha^{-1}) and Yeanelo 4 (5.23 t ha^{-1}). The maximum grain yield (6.32 t ha^{-1}) in Theehtatyin variety might be attributed to the production of maximum effective tillers m^{-2}. Uddin et al. (2010) ; Ali et al. (2014); Shiyam et al. (2014) reported that the varieties which produced higher number of effective tillers $hill^{-1}$ and higher number of grains $panicle^{-1}$showed higher grain yield ha^{-1}.

Grain yield of different sowing methods as affected by tested rice varieties were observed in (Table 4.6). There were not significant differences among the sowing methods at ($Pr = 0.12$). The grain yield of rice ranged from (5.44 t ha^{-1}) to (6.02 t ha^{-1}). The grain yield of Drum seeder (6.02 t ha^{-1}) resulted as the maximum yield but it was not significance from the grain yield of the Line sowing (5.44 t ha^{-1}) and Broadcasting (5.52 t ha^{-1}). This was due to number of spikelets $panicle^{-1}$ and panicle length. Yield variation in the method of sowing could be due to better establishment or growth of rice plants as a result of lesser competition for water, sunlight and nutrients.

There was no interaction between the varieties and sowing methods ($Pr = 0.44$). This means that the changes of grain yield in sowing methods were influenced by the tested varieties.

Although the grain yields of all tested varieties were not significantly differences at the different sowing methods, they had differences in numerical values (Figure 4.14). The maximum grain yield resulted from the Theehtatyin (6.12 t ha^{-1}) whereas the minimum grain yield resulted from Yeanelo 4 (4.88 t ha^{-1}) at Broadcasting. In Line sowing, Theehtatyin gave the maximum grain yield (5.9 t ha^{-1}) and the minimum grain yield (5.01 t ha^{-1}) was observed from the Yeanelo 1. In the case of the Drum seeder, Theehtatyin obtained the maximum grain yield (6.95 t ha^{-1}) whereas Yeanelo 4 gave the minimum grain yield (4.89 t ha^{-1}).

Among the tested varieties, Theehtatyin variety showed the highest grain yield (6.32 t ha^{-1}), which was significantly associated in yield attributing characters especially number of panicles m^{-2}. Thakur (1993) noted that number of panicles is the most important factor that causes variation in the grain yield of rice. The realization of high yield potential for rice was closely related to the improved sink size, such as more panicles per square meter and grains per panicle (Chen et al. 2008).

Although there was no statistically difference in grain yield among the sowing methods, the Broadcasting method gave the lowest grain yield (5.52 t ha^{-1}). It was due to excessive tillering, which leads to high tiller abortion, poor grain setting, small panicle size, and further reduced grain yield (Peng et al. 1994; Ahmad et al. 2005), resulting the lowest spikelets $panicle^{-1}$. Lower light interception due to higher vegetative biomass and uneven space and aeration resulted in minimum number of spikelets per panicle in soaked seed broadcast. Drum seeder method recorded the highest average yield because the sowing distance ensure air circulation, water and light which are basic factors necessary for photosynthesis (Baloch et al. 2002).

Mamun (2005) observed that Line sowing method showed better performance than broadcast method. Bari (2004) also found significantly higher grain yield from direct wet seeded Line sowing method than other methods.

4.2.1.2 Number of panicles m^{-2}

There was significantly different ($Pr < 0.02$) in the number of panicles m^{-2} among the tested varieties (Table 4.6). The number of panicles m^{-2} of rice ranged from (424.67) to (595.33). The results showed that the maximum number of panicles m^{-2} (595.33) was found from Theehtatyin and followed by Yeanelo 1 (441.56) and Yeanelo 4 (424.67) which was statistically similar effects.

Similarly, there were significantly differences ($Pr < 0.001$) in the number of panicles m^{-2} of the tested varieties among the sowing methods (Table 4.6). The number of panicles m^{-2} of rice ranged from (304.00) to (730.44). The maximum numbers of panicles m^{-2} were resulted from the Broadcasting (730.44) and Line sowing (427.11). Drum seeder show the minimum number of panicles m^{-2} (304.00).

There was interaction between sowing methods and tested varieties ($Pr < 0.01$) (Table 4.6). This means that changes of the numbers of panicles m^{-2} in the sowing methods was influenced by varieties.

Number of panicles m^{-2} ranged from (248.00) to (923.33) (Figure 4.15). At the Broadcasting, Theehtatyin gave the maximum number of panicles m^{-2} (923.33) whereas Yeanelo 4 gave the minimum number of panicles m^{-2} (624.00). In case of the Line sowing, the highest number of panicles m^{-2} (511.33) resulted from Theehtatyin whereas the lowest number of panicles m^{-2} (402.00) resulted from Yeanelo 4. Similarly, at the Drum seeder, Theehtatyin was the maximum number of panicles m^{-2} (351.33) and Yeanelo 4 was the minimum number of panicles m^{-2} (248.00).

According to the results, Theehtatyin gave the maximum number of panicles m^{-2} and Yeanelo 4 gave the minimum number of panicles m^{-2} at all the sowing methods. This variation in the number of panicles m^{-2} was due to genetic make-up of varieties. Theehtatyin had higher seed rate regarding with small seed size among the tested rice varieties. Therefore number of panicles m^{-2} in Theehtatyin was higher at all sowing methods.

In direct seeding system, the number of panicles per square meter is largely determined on the seedling rate and percentage of emergence. These results were supported by Pedroso and Mariot (1986) and Sharma (1994) who reported that seeding rate was increase, the panicle bearing m^{-2} increased significantly.

Table 4.6 Mean effects of varieties and sowing methods on yield and yield component characters of rice in Maubin

Treatment	Grain yield ($t\ ha^{-1}$)	Panicles m^{-2} (no.)	Spikelets $panicle^{-1}$ (no.)	Filled grain (%)	1000-grain weight (g)
Varieties					
Theehtatyin	6.32 a	595.33 a	68.14	62.61 b	20.70 c
Yeanelo 4	5.23 b	424.67 b	79.15	70.82 ab	23.79 a
Yeanelo 1	5.42 b	441.56 b	78.29	79.16 a	23.03 b
$LSD_{0.05}$	**0.70**	**98.16**	**14.95**	**8.76**	**0.51**
Methods					
Broadcasting	5.52	730.44 a	54.32 c	70.83	22.41
Line sowing	5.44	427.11 b	76.54 b	71.21	22.54
Drum seeder	6.02	304.00 c	94.72 a	70.55	22.58
$LSD_{0.05}$	**0.61**	**49.43**	**6.78**	**1.80**	**0.46**
Pr>F					
Variety	0.03	0.02	0.19	0.02	<0.001
Method	0.12	<0.001	<0.001	0.73	0.69
Var * Method	0.44	0.01	0.24	0.31	0.08
CV_a (%)	**9.50**	**15.39**	**15.20**	**9.45**	**1.74**
CV_b (%)	**10.47**	**9.88**	**8.76**	**2.48**	**1.97**

In each column, means having a common letter are not significantly different at 5% LSD.

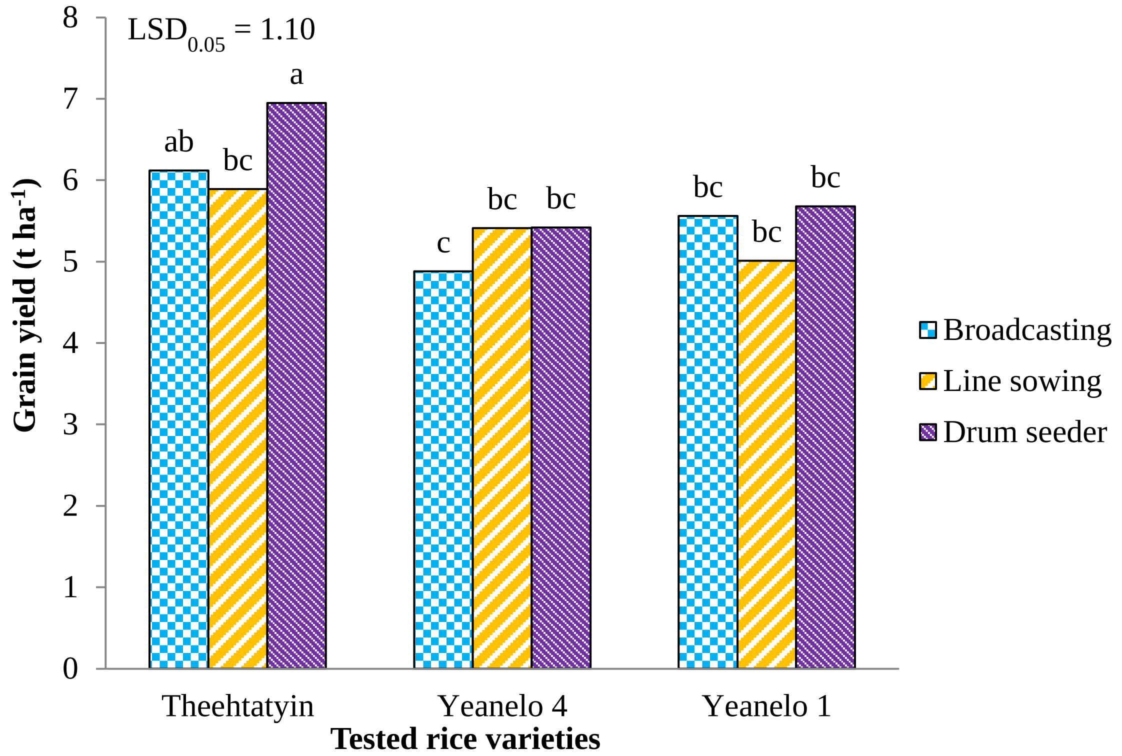

Figure 4.14 Mean comparison of grain yield as affected by the tested rice varieties and sowing methods in Maubin

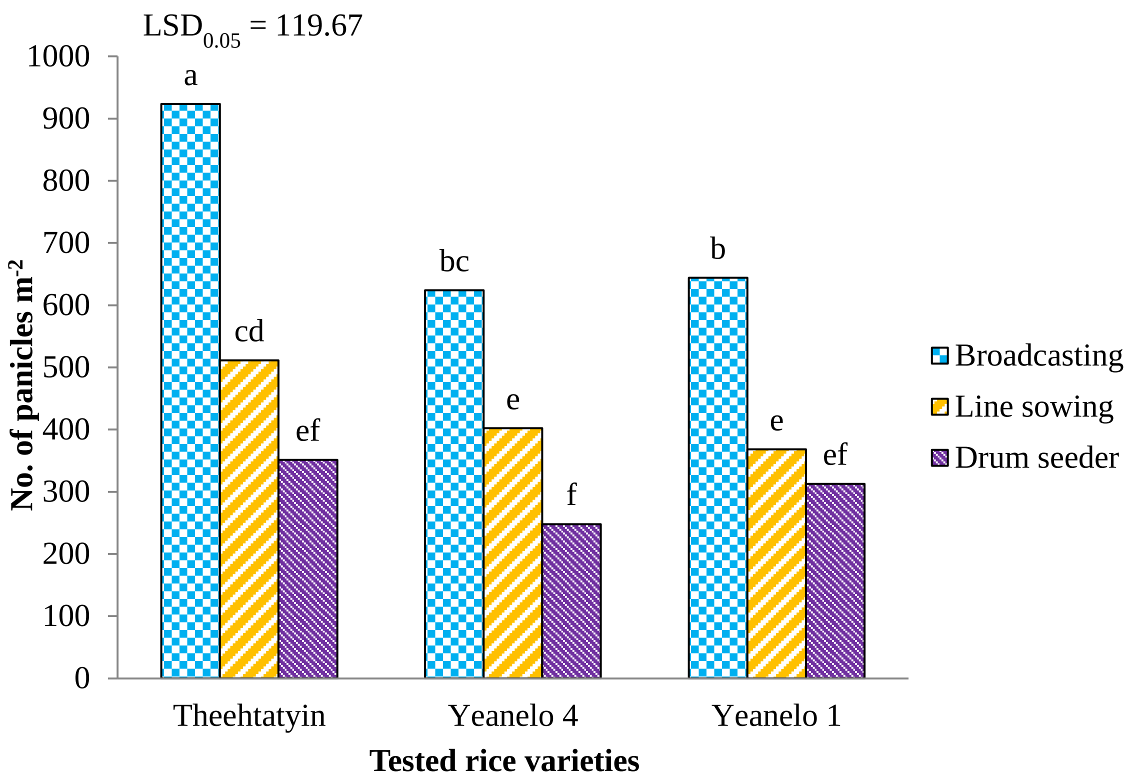

Figure 4.15 Mean comparison of number of panicles m^{-2} as affected by the tested rice varieties and sowing methods in Maubin

4.2.1.3 Number of spikelets panicle^{-1}

The mean values of the number of spikelets panicle^{-1} of the tested rice varieties indicated that the data analysis of variance were not significant difference (Pr = 0.19) (Table 4.6). Yeanelo 4 was observed in the highest spikelets panicle^{-1} (79.15). The lowest value in spikelets panicle^{-1} (68.14) was attained from Theehtatyin, however, it was not significantly different from Yeanelo 4 (79.15) and Yeanelo 1 (78.29).

The mean effect in the number of spikelets panicle^{-1} as affected by sowing methods showed significantly different (Pr < 0.001) (Table 4.6). The highest number of spikelets panicle^{-1} (94.72) was resulted from Drum seeder, Line sowing (76.54) was followed and the lowest value (54.32) from Broadcasting.

There was no interaction in the number of spikelets panicle^{-1} between the tested varieties and sowing methods (Pr = 0.24) (Table 4.6). It means that the change in mean values of the number of spikelets panicle^{-1} was not influenced by sowing methods.

Number of spikelets panicle^{-1} ranged from (51.03) to (101.11) (Figure 4.16). At the Broadcasting, the maximum number of spikelets panicle^{-1} (57.44) was resulted from Yeanelo 4 while the minimum number of spikelets panicle^{-1} (51.03) was resulted from Theehtatyin. In Line sowing, the maximum number of spikelets panicle^{-1} (85.25) was observed from Yeanelo 4 and the minimum number of spikelets panicle^{-1} (65.11) was observed from Theehtatyin. Yeanelo 1 gave the maximum number of spikelets panicle^{-1} (101.11) and Theehtatyin gave the minimum number of spikelets panicle^{-1} (88.29) at Drum seeder.

The result indicated that Theehtatyin, Yeanelo 4 and Yeanelo 1 were significantly different in the number of spikelets panicle^{-1} (68.14), (79.15) and (78.29) respectively. This variation in the production of number of spikelets per panicle was due to the genetic make-up of varieties. Hossain et al. (1991) reported that the number of spikelets per panicle was influenced by variety.

Greater number of spikelets panicle^{-1} at Drum seeder sowing method was due to greater availability of photosynthats due to less intra-plant competition, which resulted in better panicle development causing more appropriation and more number of spikelets panicle^{-1}. These results are supported by Aslam et al. (2002) who reported that maximum number of spikelets panicle^{-1} at the lower seeding densities.

4.2.1.4 Filled grain percentage

There was significant difference (Pr < 0.02) in filled grain percent among the tested varieties as affected by the sowing methods (Table 4.6). The highest filled grain percent (79.16) was resulted from Yeanelo 1 which was statistically difference from Yeanelo 4 (70.82). The lowest filled grain percent (62.61) was observed from Theehtatyin.

The filled grained percent of Drum seeder (70.55), Line sowing (71.21) and Broadcasting (70.83) were not statistically difference among the sowing methods

Significant interaction was not observed in filled grain percent between the tested varieties and sowing methods (Pr = 0.31). It explains that mean values of filled grain percent in varieties were not influenced by the sowing methods.

Filled grain percent ranged from (61.84) to (80.01) (Figure 4.17). At the Broadcasting method, the maximum mean value of filled grain percent of Yeanelo 1 (79.18) was significantly difference from other varieties, Yeanelo 4 (71.48) and Theehtatyin (61.84). In Line sowing method, Yeanelo 1 variety gave the maximum filled grain percent (80.01) and Theehtatyin gave the minimum filled grain number (62.18). Likewise, Drum seeder, the maximum filled grain percent (78.30) was resulted from Yeanelo 1 and minimum number of filled grain percent (63.82) was resulted from Theehtatyin.

The highest number of filled grain percent (79.16) was observed at Yeanelo 1 variety. However, the filled grain percent of Yeanelo 4 (70.82) was not significant difference from Yeanelo 1 (79.16). Among the tested rice varieties, the minimum filled grain percent (62.61) was observed from Theehtatyin variety due to highest number of panicles m^{-2}. Dingkuhn et al. (1990) reported that intra-plant competition resulted in reduced spikelet fertility and incomplete filled spikelets especially in later panicles. Yoshida (1981) also reported that factors such as weather, soil, fertilizer application and incidence of pests affect filled spikelets or sterility percentage.

Among the sowing methods, filled grain percent of Drum seeder (70.55) was not significantly higher than the other methods, Broadcasting (70.83) and Line sowing (71.21). It was due to lowest number of panicles m^{-2} in Drum seeder method. Therefore, it was attributed to less competition and better utilization of resources at grain filling stage. This result is similar with Aslam et al. (2002) who reported lower percentage of normal kernels at higher seeding densities.

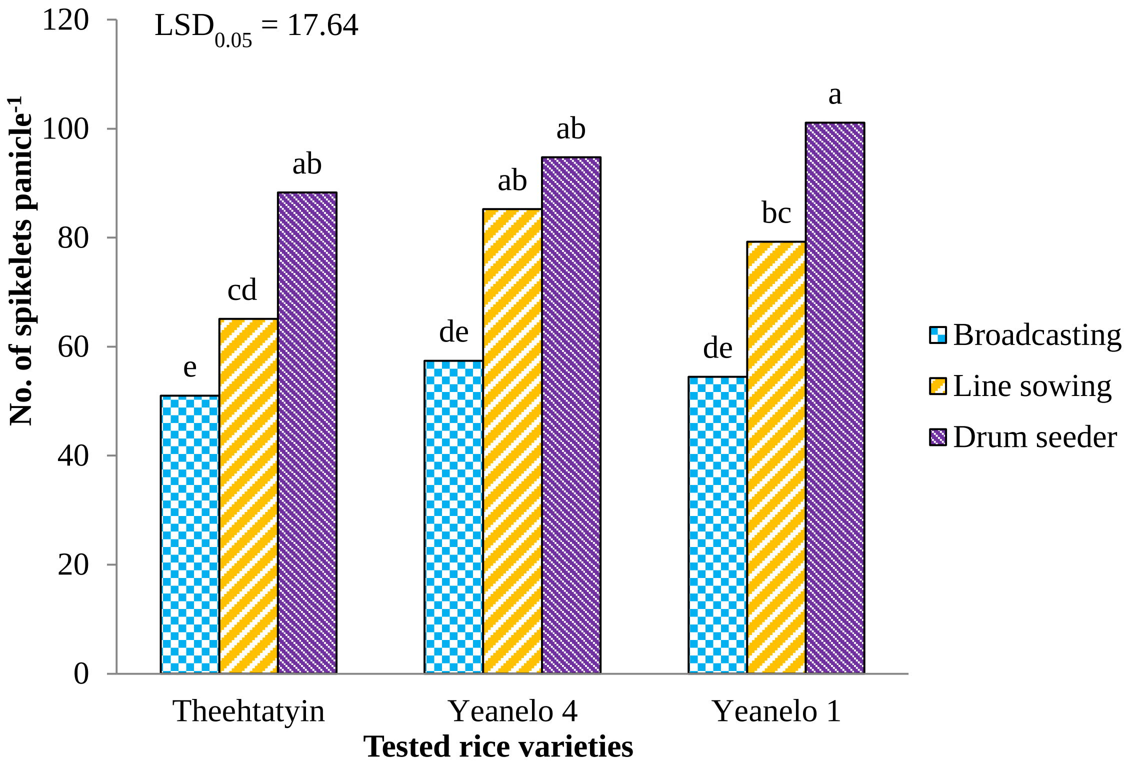

Figure 4.16 Mean comparison of number of spikelets panicle^{-1} as affected by the tested rice varieties and sowing methods in Maubin

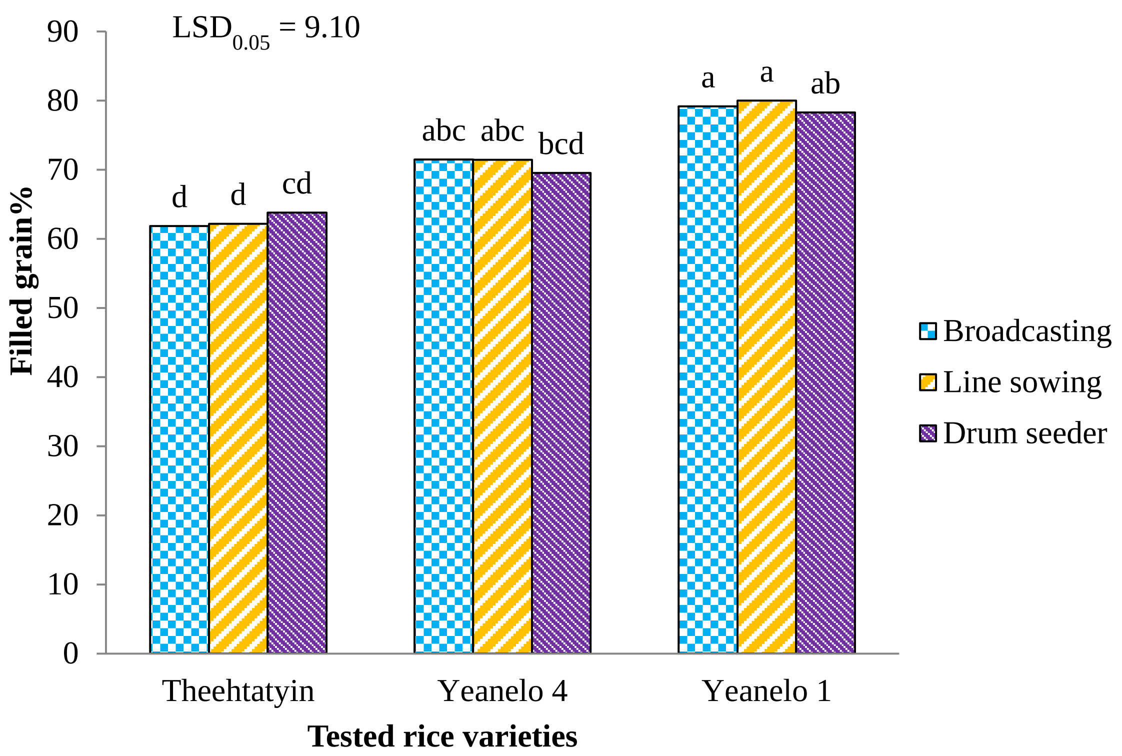

Figure 4.17 Mean comparison of filled grain percentage as affected by the tested rice varieties and sowing methods in Maubin

4.2.1.5 Thousand grain weight

The mean effects of 1000-grain weight as affected by the varieties and sowing method showed significant difference (Pr < 0.001) in (Table 4.6). Although the maximum number of 1000-grain weight (23.79 g) was from Yeanelo 4, which was significantly difference from that of Yeanelo 1 (23.03 g) and Theehtatyin (20.70 g).

Thousand-grain weight was not significant difference among the sowing methods (Pr = 0.69) (Table 4.6). The mean value of thousand-grain weight was in Drum seeder (22.58 g), Line sowing (22.54 g) and Broadcasting (22.41 g).

There was no interaction in mean values of 1000-grain weight between the tested varieties and sowing methods (Pr = 0.08). It means that change of mean values of the varieties was not influenced by the sowing methods.

Mean values of 1000-grain weight were ranged from (20.08 g) to (23.94 g) (Figure 4.18). Significantly difference of 1000-grain weight was not observed among the tested varieties except Theehtatyin (20.08 g) at the Broadcasting. The maximum number of 1000-grain weight (23.81 g) was produced from Yeanelo 4. At the Line sowing, there was significant difference of 1000-grain weight among the varieties. The maximum number of 1000-grain weight (23.63 g) was observed from Yeanelo 4 whereas the minimum number of 1000-grain weight (21.08 g) was obtained from Theehtatyin at Line sowing. In case of the Drum seeder, significant difference was occurred among the varieties. Yeanelo 4 gave the maximum number of 1000-grain weight (23.94 g) and Theehtatyin gave the minimum number of 1000-grain weight (20.94 g).

These result indicated that the mean values of 1000-grain weight of the Yeanelo 4 (23.79 g) was statistically similar and which were significantly difference from that of Yeanelo 1 (23.03 g) and Theehtatyin (20.70 g). Ashraf et al. (1999) indicated that 1000-grain weight, an important yield-determining component, is a genetic character least influenced by the environment.

Among the sowing methods, the result indicated that there was no significantly difference in mean values of the 1000-grain weight. Matsushima (1980) reported that 1000-grain weight was less influenced by the treatment because it is more or less genetically controlled characteristics. It is usually a stable varietal character and the management practice has less effect on its variation (Yoshida 1981).

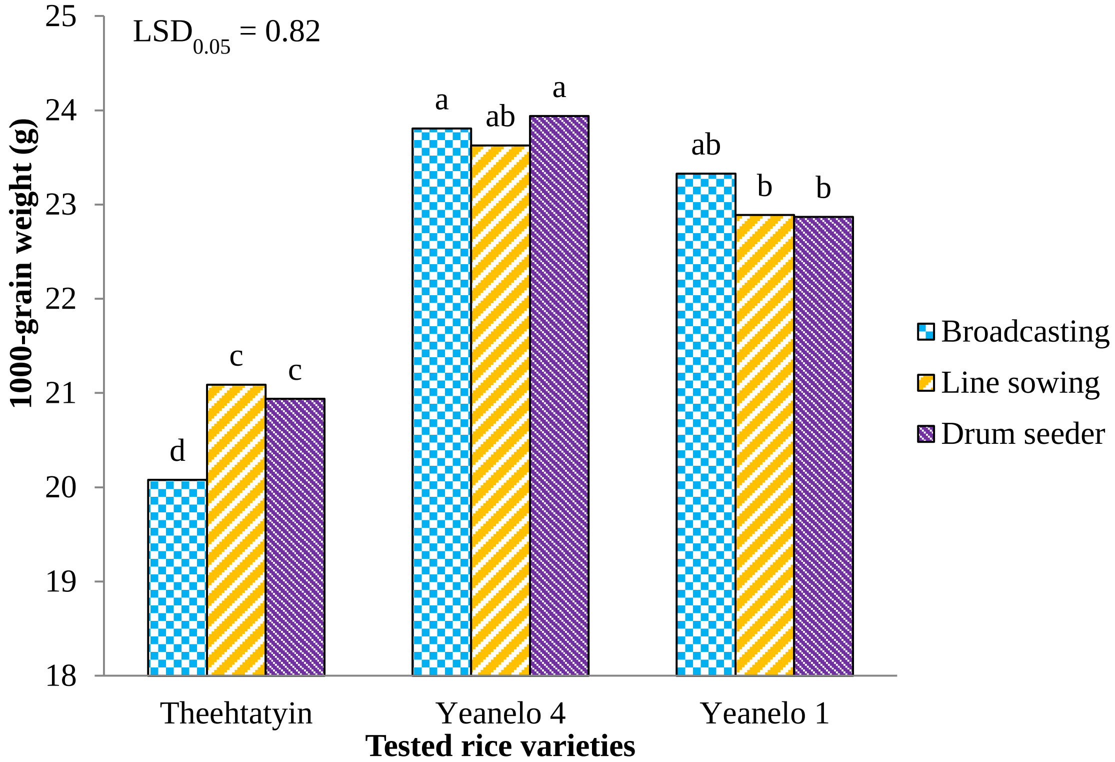

Figure 4.18 Mean comparison of 1000-grain weight as affected by the tested rice varieties and sowing methods in Maubin

4.2.2 Agronomic characters

4.2.2.1 Number of seedlings m^{-2}

Number of seedlings m^{-2} of tested rice varieties as affected by different sowing methods is described in (Figure 4.19). Number of seedlings m^{-2} was recorded at 14 DAS. The highest number of seedlings was obtained at Theehtatyin among the sowing methods. The maximum number of seedlings m^{-2} (505.33) was obtained from Theehtatyin variety whereas the minimum number of seedlings m^{-2} (440.44) was observed from Yeanelo 4 and followed by Yeanelo 1 (454.22). This differences was due to genetic character of variety especially seed size.

There was no interaction between the tested rice varieties and sowing methods at 14 DAS, ($Pr = 0.85$). However, there was significant difference of mean effect of sowing methods in number of seedlings m^{-2} of the tested rice varieties at ($Pr < 0.001$). Number of seedlings m^{-2} of the Broadcasting (755.33) was higher than Line sowing (281.17) and Drum seeder (121.17). This variation in the number of seedlings m^{-2} was due to initial seeding density of the varieties.

Number of seedlings m^{-2} ranged from (114.00) to (990.67) (Figure 4.19). The mean effect of number of seedlings m^{-2} was not significantly different among the tested varieties at the Broadcasting. The maximum number of seedlings m^{-2} (990.67) was resulted from Theehtatyin whereas the minimum number of seedlings m^{-2} (863.33) was resulted from Yeanelo 1 at Broadcasting. At Line sowing, Theehtatyin gave the maximum number of seedlings m^{-2} (375.33) and Yeanelo 4 gave the minimum number of seedlings m^{-2} (308.67) in Line sowing. In case of Drum seeder, the maximum number of seedlings m^{-2} (158.67) was resulted from Yeanelo 1 and the minimum number of seedlings m^{-2} (114.0) was resulted from Yeanelo 4. There was no significant difference among the tested varieties under the Drum seeder.

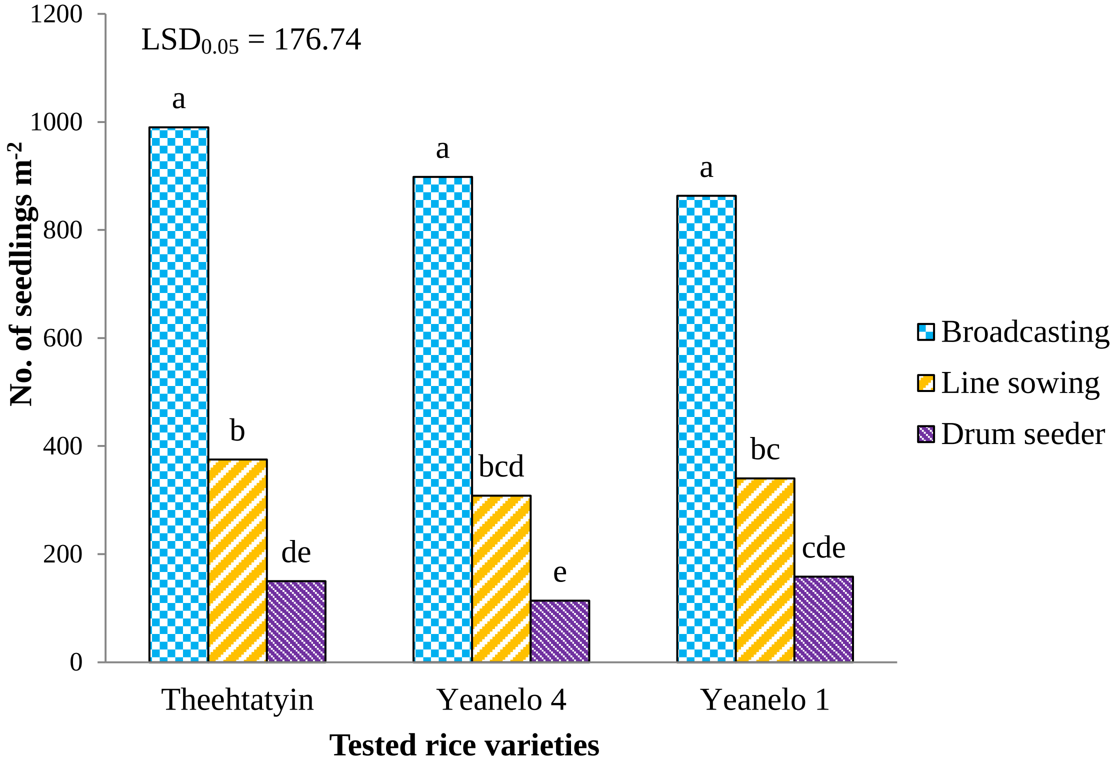

Figure 4.19 Mean comparison of the number of seedlings m^{-2} at 14 DAS as affected by the tested rice varieties and sowing methods in Maubin

4.2.2.2 Plant height

Plant heights as affected by different sowing methods and rice varieties at different growth stages in Maubin are shown in (Figure 4.20). The plant heights of all varieties were gradually increased until 84 DAS under different sowing methods. Among varieties, significantly difference of plant heights was found firstly at 56 DAS until 84 DAS. In the different sowing methods, Line sowing showed the highest plant height in Yeanelo 4. However, Drum seeder showed the highest plant height in Theehtatyin and Yeanelo 1. It was due to less competition for resources between the plants. Awan et al. (2007) reported that the difference in plant height was due to different establishment methods while maximum plant height in planting with 20 cm spacing was due to specific distance and which leading to reduced competition.

There was significant difference ($Pr < 0.001$) in plant height among the tested rice varieties at 56 DAS, 70 DAS and 84 DAS (Table 4.7). At 84 DAS, the maximum plant height (103.42 cm) was from Yeanelo 4 and Yeanelo 1 (102.40 cm). The lower plant height (77.79 cm) was from Theehtatyin. It was due to the fact that all tested rice varieties were tall cultivars except Theehtatyin, which was semi-dwarf in nature.

There was not significantly difference among the sowing methods at 84 DAS, ($Pr = 0.37$) (Table 4.7). Significant interaction was not observed in plant height between the tested rice varieties and sowing methods at 84 DAS, ($Pr = 0.48$) (Table 4.7). It explains that mean values of plant height in varieties were not influenced by the sowing methods.

The combined effect of tested rice varieties and sowing methods at 84 DAS showed in (Figure 4.21). At 84 DAS, although the maximum plant height was observed from Yeanelo 4 at Broadcasting and Line sowing, the minimum plant height was observed from Theehtatyin at all sowing methods. In this study, Line sowing gave the highest plant height at Yeanelo 4 whereas Drum seeder gave the highest plant height at Theehtatyin and Yeanelo 1 varieties. It means that the difference in plant height was due to specific distance of plants leading to reduced competition. Vijayakumar et al. (2006) also reported that plants got sufficient space to grow and increased light transmission in the canopy led to increased plant height. However, Baset Mia and Shamsuddin (2011); Mercado and Garrity (1993) reported that the variation in growth and development among the rice varieties could be attributed to the genetic characteristics or environmental factors such as temperature, photoperiods, light intensity, soil factors and cultural manipulation such as plant density, sowing methods and moisture supply.

Table 4.7 Mean effects of tested rice varieties and sowing methods on plant height of rice in Maubin

Treatment	**Plant height (cm)**					
	14 DAS	**28 DAS**	**42 DAS**	**56 DAS**	**70 DAS**	**84 DAS**
Variety						
Theehtatyin	14.53 a	25.58	38.09 b	52.99 c	60.89 c	77.79 b
Yaenelo 4	13.11 b	25.91	40.38 ab	58.37 b	74.34 b	103.42 a
Yaenelo 1	13.03 b	25.91	44.00 a	63.43 a	78.67 a	102.40 a
$LSD_{0.05}$	**1.10**	**1.90**	**3.89**	**1.96**	**3.84**	**6.30**
Method						
Bradcasting	13.66	24.98	39.71	56.24 b	69.62 b	92.01
Line sowing	13.62	26.13	41.77	60.01 a	71.16 ab	95.82
Drum seeder	13.40	26.28	40.99	58.53 ab	73.12 a	95.78
$LSD_{0.05}$	**0.55**	**1.79**	**2.73**	**3.66**	**3.46**	**6.49**
Pr>F						
Variety	0.03	0.85	0.03	<0.001	<0.001	<0.001
Method	0.56	0.27	0.29	0.12	0.13	0.37
Var * Method	0.30	0.31	0.79	0.38	0.47	0.48
CV_a (%)	**6.18**	**5.63**	**7.27**	**2.57**	**4.12**	**5.09**
CV_b (%)	**3.95**	**6.76**	**6.52**	**6.12**	**4.73**	**6.68**

In each column, means having a common letter are not significantly different at 5% LS.

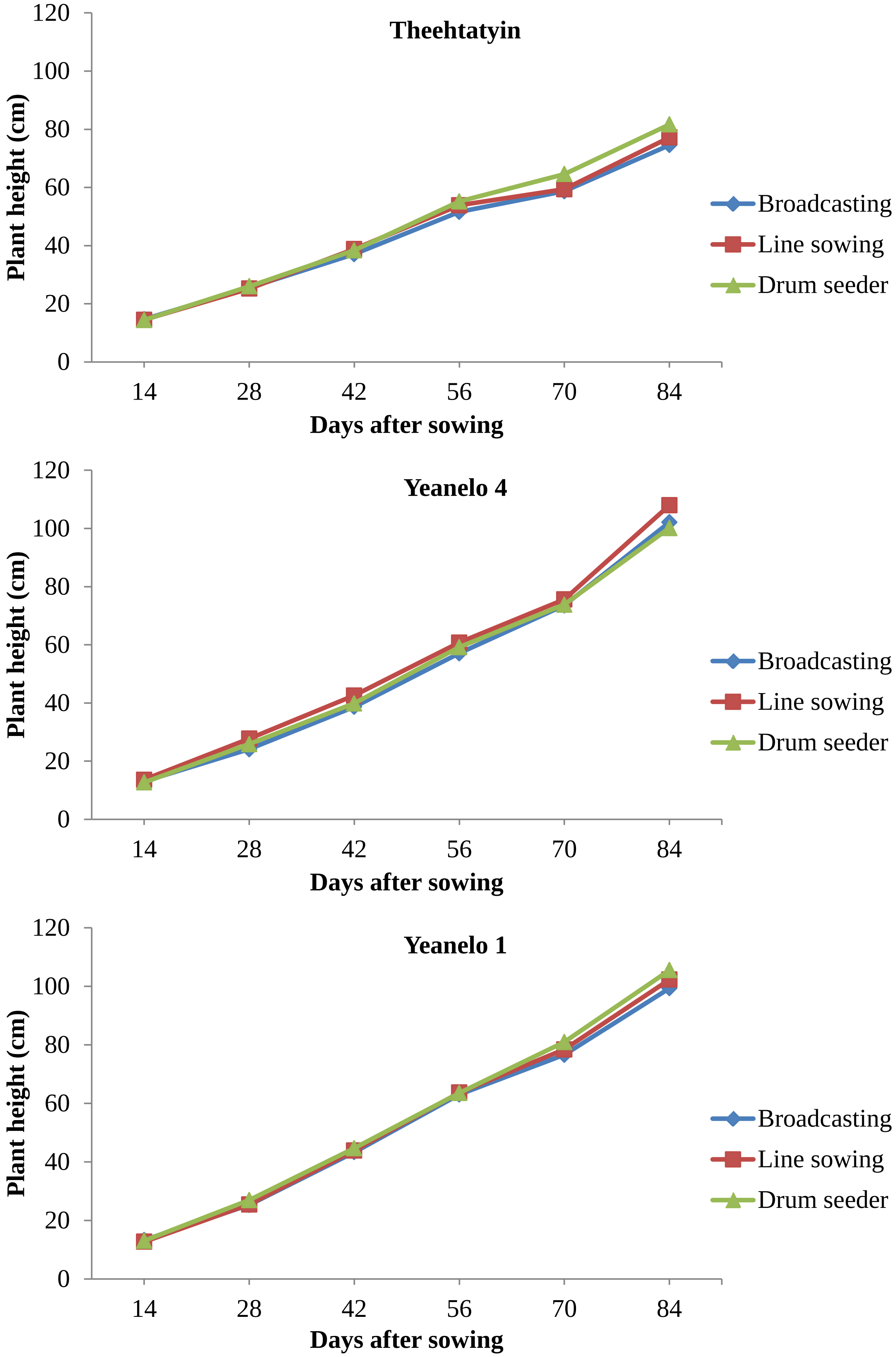

Figure 4.20 Plant height as affected by tested rice varieties and sowing methods in Maubin

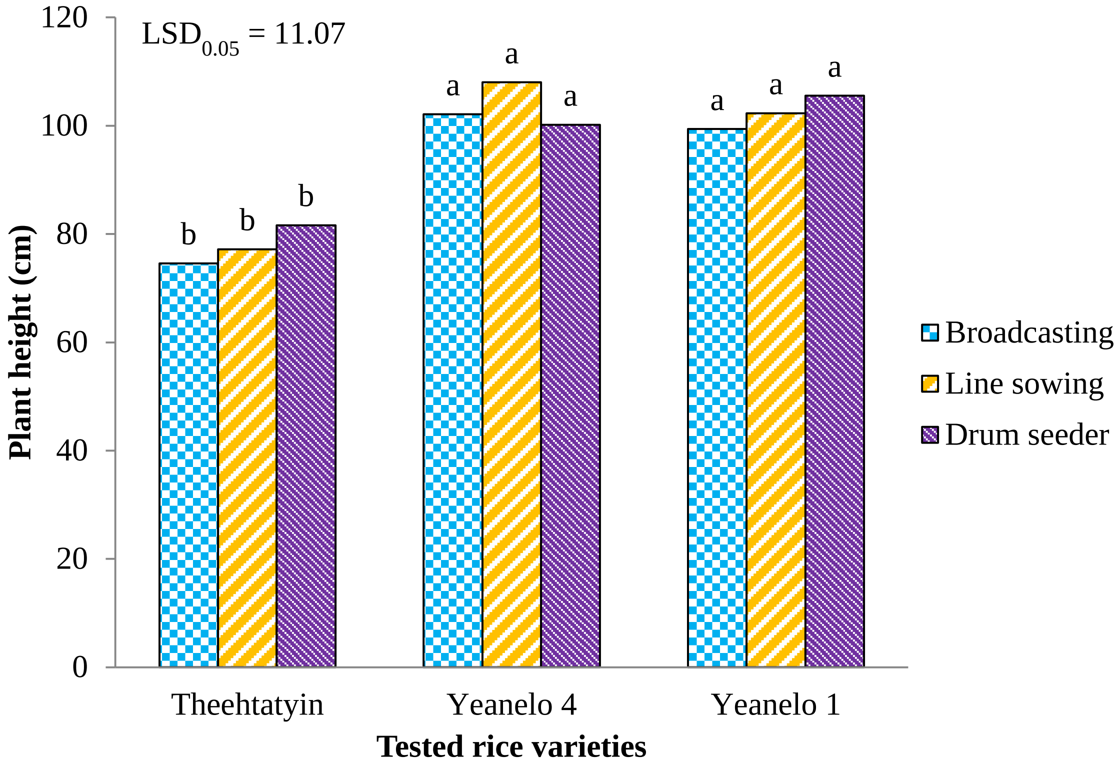

Figure 4.21 Mean comparison of plant height at 84 DAS as affected by the tested rice varieties and sowing methods in Maubin

4.2.2.3 Number of productive tillers m^{-2}

Number of productive tillers m^{-2} was recorded at weekly interval from 14 DAS to 84 DAS. Numbers of productive tillers m^{-2} as affected by rice varieties and sowing methods at different growth stages in dry season, 2016 are shown in (Figure 4.22**)**. The highest number of productive tillers was obtained at 56 DAS under different sowing methods. At all growth stages, the maximum number of productive tillers m^{-2} were obtained from Theehtatyin variety whereas the minimum number of productive tiller m^{-2} was observed from Yeanelo 4. This differences was due to genetic character of variety especially seed size.

Except at 56 DAS ($Pr < 0.009$) and 84 DAS ($Pr < 0.003$), there was no interaction between the tested rice varieties and sowing methods at all growth stages (Table 4.8). This means that changes of number of productive tillers m^{-2} in tested rice varieties was not influenced by the different plating methods. Number of productive tillers m^{-2} (813.56) from Theehtatyin was higher than the other tested rice varieties, Yeanelo 4 (581.78), Yeanelo 1 (597.33).

There was significant difference of mean effect of sowing methods in number of productive tillers m^{-2} of the tested rice varieties at ($Pr < 0.001$) (Table 4.8). Number of productive tillers m^{-2} of the Broadcasting (964.50) was higher than Line sowing (512.17) and Drum seeder (416.00).

There was interaction between the tested rice varieties and sowing methods ($Pr = 0.003$) (Table 4.8). This means that changes of number of productive tillers m^{-2} in tested varieties was influenced by the different sowing methods.

Number of productive tillers m^{-2} ranged from (345.3) to (1261.3) (Figure 4.23). The mean effect of number of productive tillers m^{-2} was significantly different among the tested varieties at the Broadcasting. The maximum number of productive tillers m^{-2} (1261.3) was resulted from Theehtatyin whereas the minimum number of productive tillers m^{-2} (888.0) was resulted from Yeanelo 1 at Broadcasting. At Line sowing, Theehtatyin gave the maximum number of productive tillers m^{-2} (684.7) and Yeanelo 4 gave the minimum number of productive tillers m^{-2} (436.7) in Line sowing. In case of Drum seeder, the maximum number of productive tillers m^{-2} (494.7) was resulted from Theehtatyin and the minimum number of productive tillers m^{-2} (345.5) was resulted from Yeanelo 4. There was no significant difference among the tested varieties under the Drum seeder.

The result indicated that number of productive tillers m^{-2} was not significantly different among the tested varieties except Theehtatyin, which was highest number of productive tillers m^{-2} (813.56). This variation in the number of productive tillers m^{-2} among the tested varieties was due to genetic make-up of varieties. Wu et al. (1998) and Nuruzzaman et al. (2000) reported that there is a large variation in tillering capacity among rice varieties. Regarding the sowing methods, Broadcasting showed the highest number of productive tillers m^{-2} (964.5) among the other sowing methods, Line sowing (512.17) and Drum seeder (416.00). This variation in the number of productive tillers m^{-2} was due to initial seeding density of the varieties. Rice cultivars were sown using high seed rate which ultimately resulted in higher number of productive tillers per unit area. Phuong et al. (2005) and Chauhan et al. (2011) mentioned that increase in seed rate can cause an increase in number of tillers. Result of present experiment indicated that Broadcasting and Drum seeder gave the maximum and minimum number of productive tillers m^{-2} at all tested varieties and this means that changes of number of productive tillers m^{-2} in Broadcasting and Drum seeder were not influenced by tested varieties. Yoshida (1970); Fagada and De Datta (1971) and Wu et al. (1998) indicated that tiller production in rice is influenced by plant density and fertilization.

Table 4.8 Mean effects of tested rice varieties and sowing methods on the number of tillers m^{-2} of rice in Maubin

Treatment	Number of tillers m^{-2}					
	14 DAS	**28 DAS**	**42 DAS**	**56 DAS**	**70 DAS**	**84 DAS**
Variety						
Theehtatyin	505.33 a	1162.70 a	1417.30 a	1520.20 a	1319.80 a	813.56 a
Yeanelo 4	440.44 b	748.70b	880.90 c	884.20 bc	851.10 b	581.78 b
Yeanelo 1	454.22 ab	814.70 b	1020.20 b	1029.30 b	873.10 b	597.33 b
$LSD_{0.05}$	**63.95**	**98.55**	**82.59**	**185.04**	**220.47**	**116.95**
Method						
Bradcasting	755.33 a	1262.70 a	1480.20 a	1521.50 a	1416.30 a	964.50 a
Line sowing	281.17 b	724.00 b	900.00 b	977.20 b	862.3 b	512.17 b
Drum seeder	121.17 c	413.20 c	600.00 c	666.70 c	682.2 c	416.00 c
$LSD_{0.05}$	**80.43**	**194.71**	**153.46**	**131.06**	**116.54**	**36.67**
Pr>F						
Variety	0.21	0.003	<0.001	0.003	0.02	0.01
Method	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Var * Method	0.85	0.53	0.05	0.009	0.07	0.003
CV_a (%)	**14.26**	**11.90**	**4.06**	**15.02**	**21.66**	**12.87**
CV_b (%)	**22.83**	**27.18**	**15.87**	**12.03**	**14.85**	**6.93**

In each column, means having a common letter are not significantly different at 5% LSD.

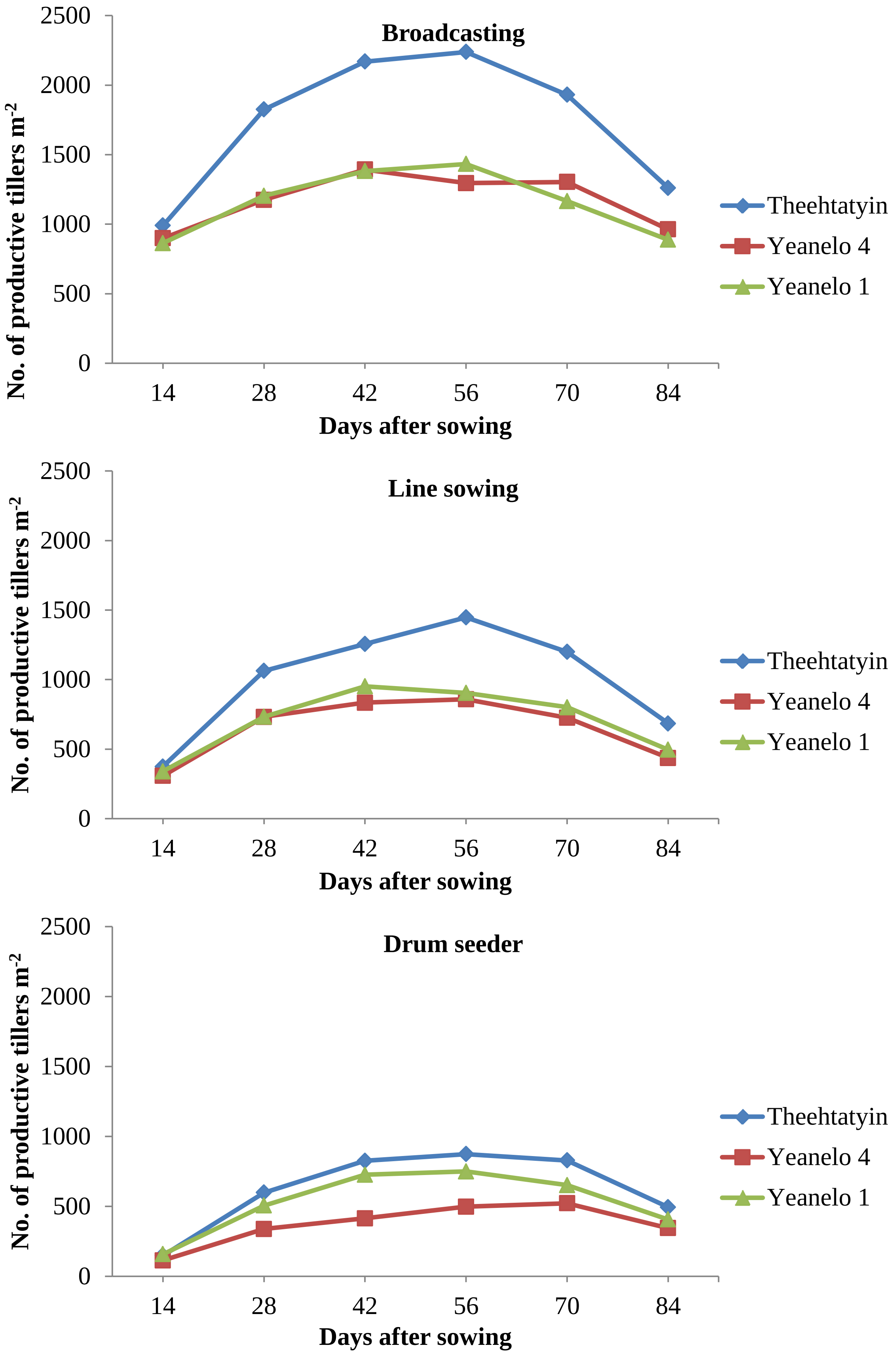

Figure 4.22 Number of productive tillers m^{-2} as affected by tested rice varieties and sowing methods in Maubin

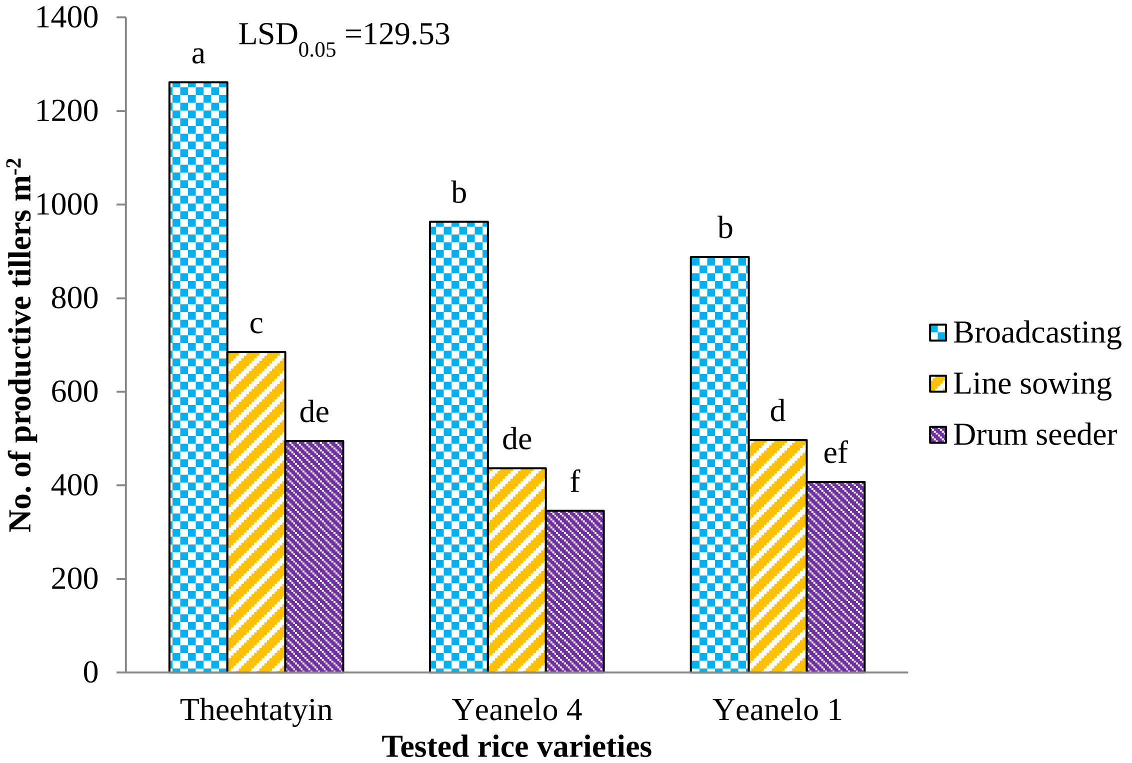

Figure 4.23 Mean comparison of the number of productive tillers m^{-2} at 84 DAS as affected by the tested rice varieties and sowing methods in Maubin

4.2.2.4 Panicle length

The significant difference of panicle length was among the observed rice varieties ($Pr < 0.001$) (Table 4.9). The maximum number of panicle length (22.39 cm) was from Yeanelo 4 and which was statistically difference from Yeanelo 1 (20.68 cm) and the minimum number of panicle length of Theehtatyin (18.33cm).

There was significant difference of panicle length in sowing methods ($Pr < 0.02$) (Table 4.9). Among the sowing methods, the maximum number of panicle length was observed from Drum seeder method (20.97 cm) and which was not significantly different from Line sowing (20.56 cm). However, it was significantly different from minimum number of panicle length (19.87 cm) of Broadcasting.

There was no interaction in panicle length between the tested rice varieties and sowing methods ($Pr = 0.85$) (Table 4.9). It explained that changes of panicle length in varieties were not influenced by the sowing methods.

Panicle length was ranged from (17.87 cm) to (22.83 cm) (Figure 4.24). Mean effect of panicle length in varieties was significantly difference at Broadcasting. The longest panicle length (21.57 cm) was resulted from Yeanelo 4 whereas the shortest panicle length (17.87 cm) was resulted from Theehtatyin at Broadcasting. In the Line sowing, significant difference was observed. Yeanelo 4 produced the longest panicle length (22.77 cm) followed by Yeanelo 1 (20.63 cm) and Theehtatyin produced the shortest panicle length (18.27 cm). At the Drum seeder, the longest panicle (22.83 cm) was also produced from Yeanelo 4 whereas the shortest panicle length (18.87 cm) was produce from Theehtatyin.

The result indicated that the longest panicle length of Yeanelo 4 (22.39 cm) followed by Yeanelo 1 (20.68 cm) was significantly difference from Theehtatyin (18.33 cm). The difference among the varieties might be due to genetic variation. Alam et al. (2012) reported that panicle length varied significantly due to different varieties.

There were significant differences of panicle length among the sowing methods. Drum seeder produced the longest panicle length (20.97 cm) followed by Line sowing (20.56 cm) and then Broadcasting (19.87 cm) due to less competition and more appropriate between the panicles for resource utilization. Dingkuhn et al. (1991) indicated that the growth dynamics and partitioning patterns of rice depend on cultural practices, particularly on sowing methods.

4.2.2.5 Harvest index (HI)

The harvest index of the tested rice varieties as affected by sowing methods described in (Table 4.9). There was no significantly difference in harvest index among the varieties (Pr = 0.19). Harvest index ranged from (0.47) to (0.49). The maximum harvest index (0.49) was recorded from Theehtatyin which was not significantly difference from Yeanelo 4 (0.47), which closely similar with that of Yeanelo 1 (0.47).

In the sowing methods, harvest index was significant difference (Pr < 0.001) (Table 4.9). Although the maximum number of harvest index (0.50) from Drum seeder which was not statistically difference from Line sowing (0.49), which was significantly difference from minimum number of harvest index (0.45) was resulted from Broadcasting.

Interaction effect was not occurred between the tested varieties and sowing methods for harvest index (Pr = 0.26) (Table 4.9). It means that changes in harvest index of the varieties were not influenced by the sowing methods.

Harvest index ranged from (0.44) to (0.50) (Figure 4.25). The maximum harvest index (0.48) from Theehtatyin which was higher than Yeanelo 1 (0.44).The minimum harvest index (0.44) was from Yeanelo 4 at the Broadcasting. There was no significant difference in harvest index among the varieties at the Line sowing. Theehtatyin gave the maximum harvest index (0.50) whereas Yeanelo 4 gave the minimum harvest index (0.49) at Ling sowing. In case of Drum seeder, difference of mean values in harvest index was not observed among the varieties. The harvest index was similar among the varieties, Theehtatyin (0.50), Yeanelo 4 (0.49) and then the last was Yeanelo 1 (0.49) at the Drum seeder.

The result showed that except Theehtatyin produced the maximum harvest index (0.49), the harvest index of the other varieties were not significantly difference among them. This result indicated that harvest index change depended on variety. Bikash et al. (2013) also reported that harvest index (HI) differed significantly among the varieties.

However, in the sowing methods, Drum seeder produced the maximum number of harvest index (0.50) which was not significantly difference from Line sowing (0.49) and significant difference from the Broadcasting (0.45). Variations in harvest index within a crop are mainly attributed to differences in crop management (Yang et al. 2000; Guo et al. 2004; Kemanian et al. 2007; D’Andrea et al. 2008; Peltonen-Sainio et al. 2008).

Table 4.9 Mean effects of varieties and sowing methods on agronomic characters of rice in Maubin

Treatment	Panicle length (cm)	Harvest index	Total Dry Matter (t ha^{-1})
Varieties			
Theehtatyin	18.33 c	0.49 a	11.35 b
Yeanelo 4	22.39 a	0.47 a	12.49 ab
Yeanelo 1	20.68 b	0.47 a	13.22 a
LSD$_{0.05}$	**1.20**	**0.03**	**1.51**
Methods			
Broadcasting	19.87 b	0.45 b	15.21 a
Line sowing	20.56 ab	0.49 a	11.83 b
Drum seeder	20.97 a	0.50 a	10.01 c
LSD$_{0.05}$	**0.71**	**0.02**	**1.43**
Pr>F			
Variety	<0.001	0.19	0.06
Method	0.02	<0.001	<0.001
Var * Method	0.85	0.26	0.08
CV $_a$ (%)	**4.5**	**4.36**	**9.33**
CV $_b$ (%)	**3.36**	**3.18**	**11.31`**

In each column, means having a common letter are not significantly different at 5% LSD.

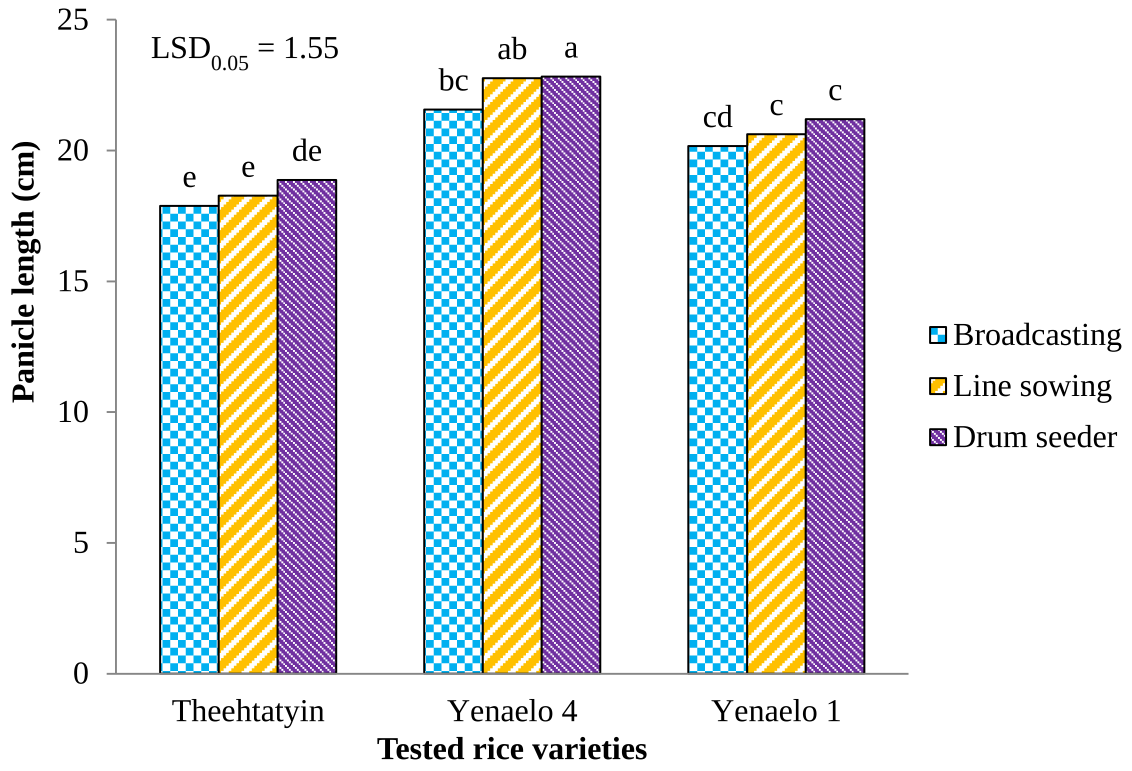

Figure 4.24 Mean comparison of the panicle length as affected by the tested rice varieties and sowing methods in Maubin

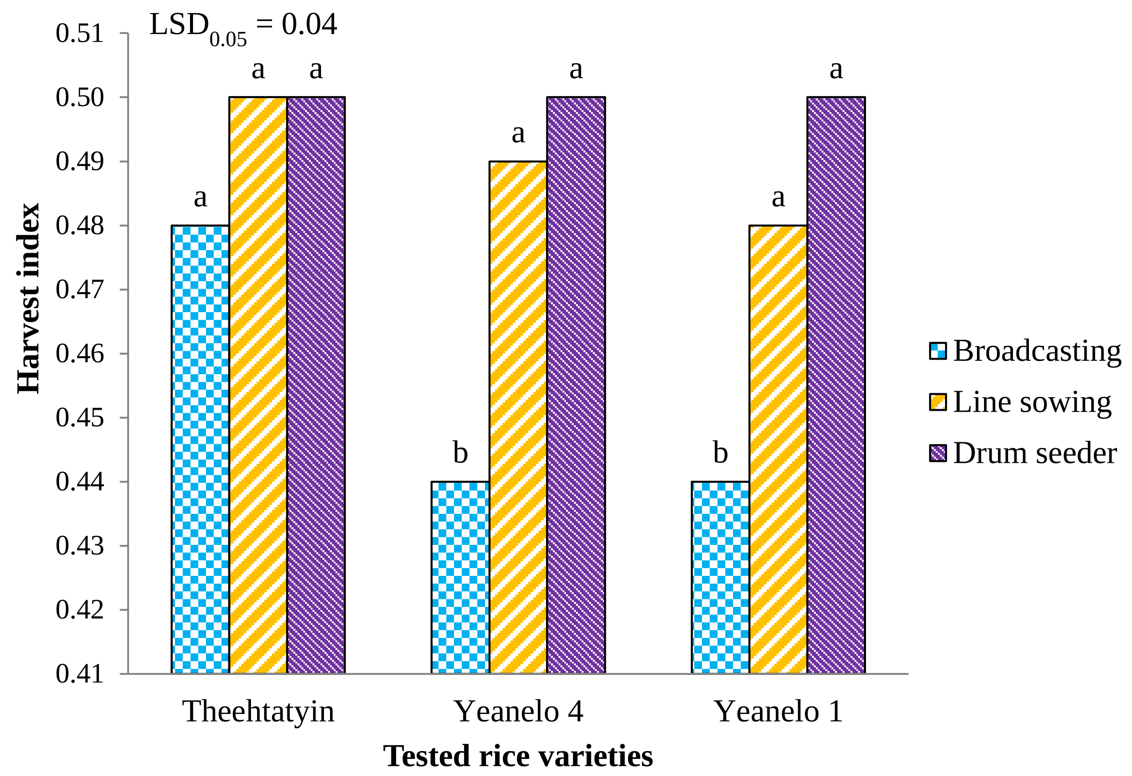

Figure 4.25 Mean comparison of harvest index as affected by the tested rice varieties and sowing methods in Maubin

4.2.2.6 Total dry matter

Mean differences of total dry matter of the tested varieties as affected sowing methods are shown at (Pr = 0.06) (Table 4.9). Although the minimum total dry matter (11.35 t ha^{-1}) of Theehtatyin was significantly difference from the maximum total dry matter (13.22 t ha^{-1}) of Yeanelo 1, which was not significantly difference from Yeanelo 4 (12.49 t ha^{-1}).

Total dry matter was highly significantly difference among the sowing methods as the ANOVA result (Pr < 0.001). The maximum number of total dry matter (15.21t ha^{-1}) from Broadcasting which was significantly difference from Drum seeder (10.01 t ha^{-1}) and Line sowing (11.83 t ha^{-1}).

Interaction was not observed between the varieties and sowing methods in case of total dry matter at (Pr = 0.08). It indicated that change of mean effect in varieties was not influenced by sowing methods.

Total dry matter was ranged from (8.75 t ha^{-1}) to (15.59 t ha^{-1}) (Figure 4.26). The maximum total dry matter (15.59 t ha^{-1}) and (15.48 t ha^{-1}) were obtained from Yeanelo 1 and Yeanelo 4 respectively and the minimum total dry matter (14.56 t ha^{-1}) was observed from Theehtatyin at Broadcasting. In the Line sowing, maximum total dry matter was (13.23 t ha^{-1}) from Yeanelo 4. At Drum seeder, maximum total dry matter (12.29 t ha^{-1}) was from Yeanelo 1 and the minimum total dry matter (8.75 t ha^{-1}) was resulted from Yeanelo 4 variety.

The result indicated that although the maximum total dry matter (13.22 t ha^{-1}) of Yeanelo 1 was significantly difference from Theehtatyin (11.35 t ha^{-1}), which was not significantly difference from Yeanelo 4 (12.49 t ha^{-1}). This result indicated that total dry matter may change depended on variety. The variation in total dry matter was found due to the variation of genetic makeup of rice varieties and also the variation in plant height, tillers and leaves number $plant^{-1}$. Reddy and Reddy (1994) observed that dry matter production and grain yields were positively and significantly associated with each other.

In the sowing methods, result showed that the maximum total dry matter (15.21 t ha^{-1}) of Broadcasting was significantly higher than the other two methods, Line sowing (11.83 t ha^{-1}) and Drum seeder (10.01 t ha^{-1}). This result showed that total dry matter was increase due to increase in plant population per square meter. Lu et al. (2004) reported that dense spacing increased the dry matter production of rice.

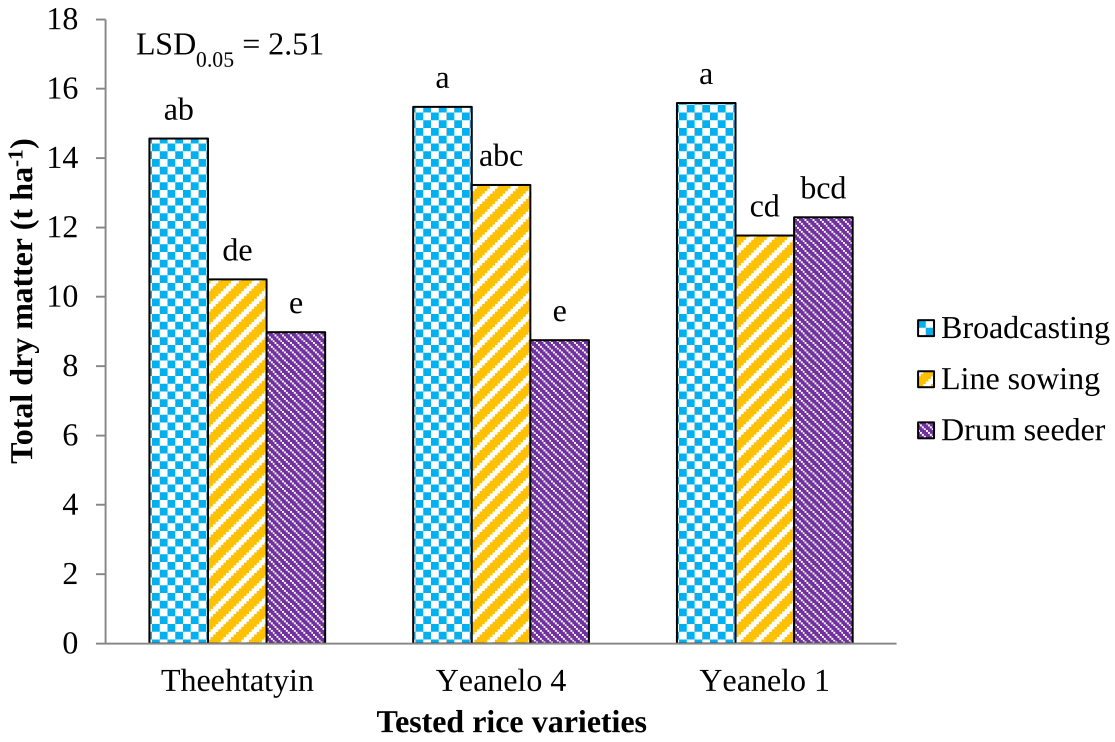

Figure 4.26 Mean comparison of total dry matter as affected by varieties and sowing methods in Maubin

4.2.3 Correlation between agronomic characters, grain yield and yield components of the tested rice varieties in Maubin

Correlation between agronomic characters, yield and yield components of the tested rice varieties in Maubin Township, Ayeyarwaddy Region during dry season, 2016 is shown in (Table 4.10). The grain yield was positively correlated with harvest index and negatively correlated with 1000-grain weight at 5% significant level. 1000-grain weight was highly positively correlated with the panicle length at 1 % level and positively correlated with filled grain percentage at 5 % level. Number of spikelets panicle^{-1} was highly negatively correlated with the number of panicles m^{-2} at 1 % level and negatively correlated with total dry matter at 5% level. Total dry matter was highly negatively correlated with harvest index at 1 % level. However, it was positively correlated with the number of panicles m^{-2} at 5 % level.

4.3 Economic Analysis of Different Sowing Methods in DaikU and Maubin

(Table 4.11) shows cost of cultivation ha^{-1}for different sowing methods in DaikU Township and Maubin Township, during dry season. In the Broadcasting method, labour needed is quiet less and time consumption is less for broadcasting the seeds. However, there is difficult in weed management due to uneven spacing of plants. Although the highest seed rate was used in Broadcasting, there was no significant difference in grain yield among the sowing methods. However, the average cost of seeds (95250 kyats) is higher than that of Line sowing (48000 kyats) and Drum seeder method (24000 kyats). In Line sowing methods, there was no difference in grain yield. However, it was time consumption for sowing the seeds. And seed rate was still higher as compare with the Drum seeder methods. Therefore, the average cost of seeds (48000 kyats) is higher than that of Drum seeder method (24000 kyats). Among the sowing methods, Drum seeder method was convenient due to less time consumption in sowing the seeds, convenience for sowing and less labour needed for seeding operation. Seed rate can also be reduced. Therefore, the average cost of seeds (24000 kyats) is lowest among the sowing methods.

The comparison of benefit cost ratio among the sowing methods in DaikU Township and Maubin Township during dry season is shown in Table 4.12. In DaikU Township, gross income of Broadcasting, Line sowing and Drum seeder methods are 1048800 kyats, 1000800 kyats and 1068000 kyats respectively. Due to lower cost of production (748719 kyats) for Drum seeder method, the benefit cost ratio (BCR) (1.43) was higher than the Line sowing (1.30), Broadcasting (1.34).

In Maubin Township, gross incomes of the sowing methods are Broadcasting (1324800 kyats), Line sowing (1305600 kyats) and Drum seeder (1444800 kyats). The highest benefit cost ratio (BCR) (1.62) was also observed in Drum seeder. Based on this finding, it can be assumed that Drum seeder method is more profitable than the Line sowing and Broadcasting methods for wet direct seeded rice growers and it can save labor and apply in areas where labor scarcity and high wage rates.

Table 4.10 Correlation between agronomic characters, yield and yield components as affected by tested rice varieties and sowing methods in Maubin

	Number of panicles m^{-2}	Filled grain (%)	Harvest index	Total dry matter (t ha^{-1})	Panicle length (cm)	Number of spikelets $panicle^{-1}$	1000 grain weight (g)	Yield (t ha^{-1})
Number of panicles m^{-2}	1							
Filled grain (%)	-0.3190	1						
Harvest index	-0.5088	-0.5097	1					
Total dry matter (t ha^{-1})	0.7189 *	0.3215	-0.8864 **	1				
Panicle length (cm)	-0.6518	0.4302	-0.0865	-0.1548	1			
Number of spikelets $panicle^{-1}$	-0.9087 **	0.2231	0.6313	-0.6894 *	0.5830	1		
1000-grain weight (g)	-0.4607	0.7004 *	-0.4605	0.1639	0.8657 **	0.2933	1	
Yield (t ha^{-1})	0.0539	-0.6173	0.7358 *	-0.4276	-0.6108	0.1124	-0.7620 *	1

* Significant different at 5% level, ** significant different at 1% level.

Table 4.11 Cost of cultivation ha^{-1} for different sowing methods of rice in DaikU and Maubin

Item	Cost of cultivation for 1 ha (Kyats)					
	DaikU			Maubin		
	Broad-casting	Line sowing	Drum seeder	Broad-casting	Line sowing	Drum seeder
Land preparation	185250	185250	185250	185250	185250	185250
Seed cost	59250	48000	24000	59250	48000	24000
Herbicide	7410	7410	7410	19820	19820	19820
Irrigation	44000	44000	44000	22000	22000	22000
Pesticides	9386	9386	9386	9386	9386	9386
Fertilizer	219500	219500	219500	219500	219500	219500
Hand weeding	0	0	0	200000	100000	150000
Harvesting, Threshing	123500	123500	123500	123500	123500	123500
Labor costs	135673	135673	135673	135673	135673	135673
Total	783969	772719	748719	974379	863129	889129

Table 4.12 Benefit Cost Ratio of rice by the different sowing methods in DaikU and Maubin

Locations	Sowing methods	Grain yield ($t\ ha^{-1}$)	Cost of production ($kyats\ ha^{-1}$)	Gross income ($kyats\ ha^{-1}$)	Benefit Cost Ratio
DaikU	Broadcasting	4.37	783969	1048800	1.34
	Line sowing	4.17	772719	1000800	1.30
	Drum seeder	4.45	748719	1068000	1.43
Maubin	Broadcasting	5.52	974379	1324800	1.36
	Line sowing	5.44	863129	1305600	1.51
	Drum seeder	6.02	889129	1444800	1.62

Local selling price, 1 basket = 5000 kyats in both locations, dry season 2016.

CHAPTER V
CONCLUSION

The present study observed the effect of sowing methods on yield and yield components of three selected rice varieties at DaikU Township, Bago (East) Region and Maubin Township, Ayeyarwaddy Region.

In both locations, mean yields were significantly different in tested rice varieties. Yeanelo 1 variety gave highest grain yield with high filled grain percent and panicle length among the tested rice varieties in DaikU Township. Although Yeanelo 1 variety had not maximum number of panicles m^{-2}, other important yield component characters that are number of spikelets panicle^{-1}, 1000 grain weight were not line in lowest level. However, Theehtatyin varieties gave the maximum grain yield producing the highest number of panicles m^{-2} than that of other rice varieties in Maubin Township. The result of the study pointed out that the drought tolerance varieties had better suitable condition than Theehtatyin variety in DaikU Township and Theehtatyin variety was more suitable for Maubin Township.

Mean yields were not significantly different in the sowing methods in both locations. However, Drum seeder gave numerically higher grain yield than that of Line sowing and Broadcasting. Although Drum seeder had minimum number of panicles m^{-2}, other characters especially number of spikelets panicle^{-1} and panicle length were superior among the tested sowing methods in both locations. And then, Drum seeder produced yield as high as the Broadcasting even though with low seed rate in it. The result of the study pointed out that although the seed rate of Drum seeder was less than Broadcasting and Line sowing, the grain yields were similar in both locations.

The results indicated that Drum seeder is efficient for rice production under the irrigated lowland direct seeding rice cultivated area. Moreover, the low seed rate can be used in Drum seeder method without affecting the yield.

Yeanelo 1 variety gave the maximum grain yield in DaikU Township whereas Theehtatyin variety produced the maximum grain yield in Maubin Township. Therefore, it can be concluded that Yeanelo 1 variety for DaikU Township and Theehtatyin variety for Maubin Township should be sown by using Drum seeder without affecting the grain yield in the study areas. Further studies should be done to obtain comprehensive information on the potential of high yielding rice varieties like tested varieties with appropriate agronomic practices under another soil condition area of Myanmar.

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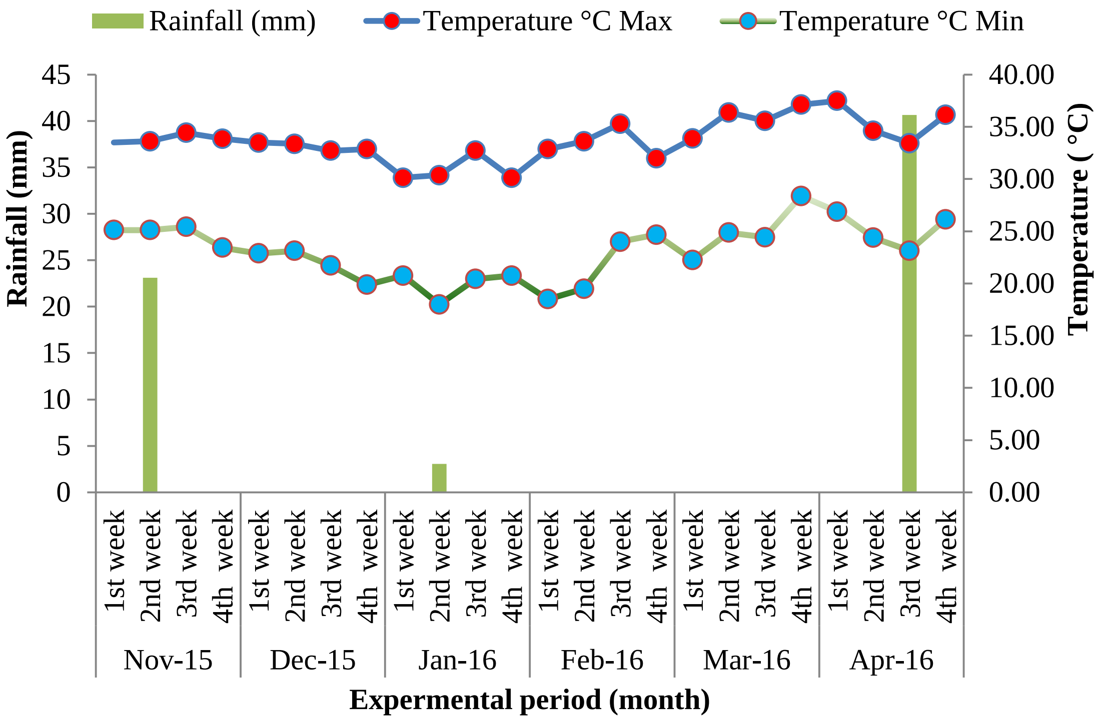
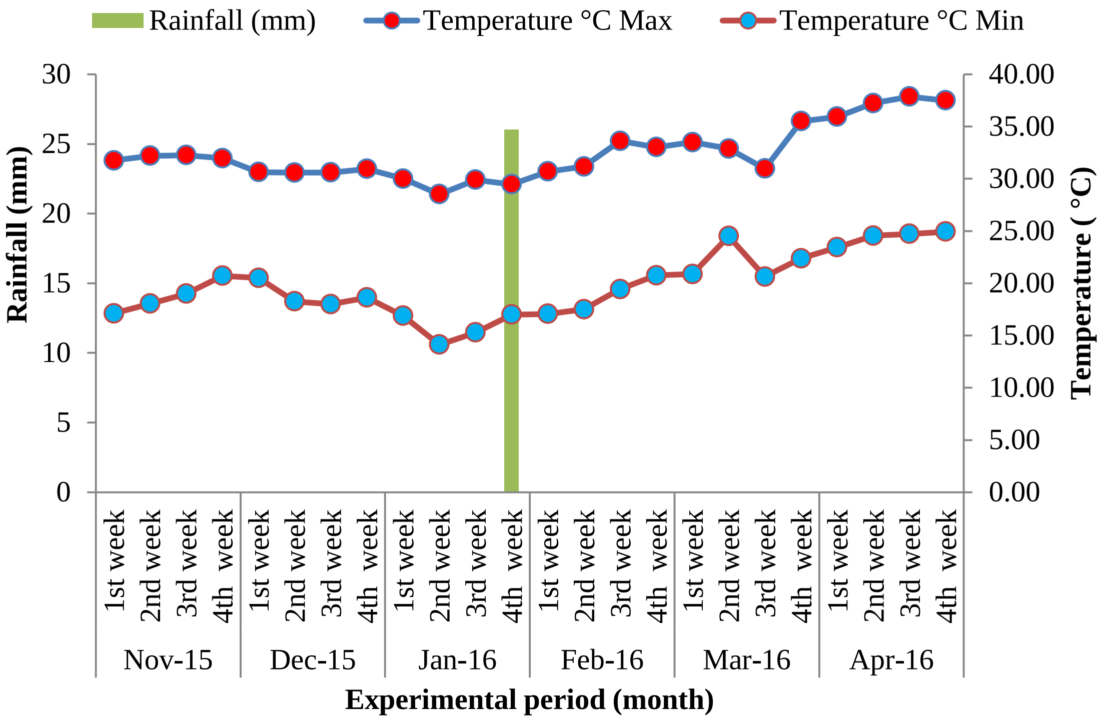
APPENDICES

Appendix 1. Weekly maximum and minimum temperature (ºC) and rainfall (mm) during the experimental period in DaikU



Appendix 2. Weekly maximum and minimum temperature (ºC) and rainfall (mm) during the experimental period in Maubin



Appendix 3. Different Sowing Methods

(a) Broadcasting

(b) Line Sowing

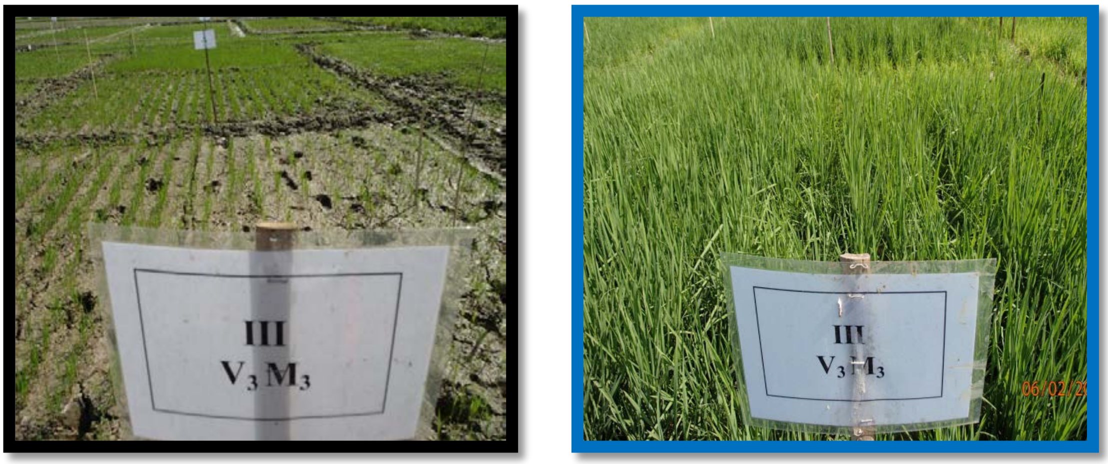
(c) Drum Seeder

Appendix 4. Performance of different sowing methods

14 DAS **56 DAS**

(a) Broadcasting

(b) Line sowing



(c) Drum seeder