# CHANGES OF RICE PRODUCTION SYSTEM IN AYEYARWADDY DELTA OF MYANMAR: A CASE STUDY IN MAWLAMYINEGYUNN TOWNSHIP

**ZAR NI MAUNG**

**OCTOBER 2019**

# CHANGES OF RICE PRODUCTION SYSTEM IN AYEYARWADDY DELTA OF MYANMAR: A CASE STUDY IN MAWLAMYINEGYUNN TOWNSHIP

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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**
**Nay Pyi Taw, Myanmar**

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The thesis attached hereto, entitled "**Changes of Rice Production System in Ayeyarwaddy Delta of Myanmar: A Case Study in Mawlamyinegyunn Township**" 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 SEIN MAUNG AND DAW WIN SEIN**

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## ABSTRACT

This study aimed to investigate the changes of rice production system between 2000 and 2018 in Mawlamyinegyunn Township, Ayeyarwaddy delta. A total of 160 sample respondents were selected from four sample villages by using purposive random sampling method in October 2018. The collected data were agronomic practices, use of family and hired labours and yields, etc. Secondary data such as climatic data, rice sown area and yields of 10 years were collected from Department of Agriculture (DOA). These results indicated that total farm size and rice growing area were not significantly changed between 2000 and 2018. It was found that the machines were widely used in land preparation in 2018 instead of using animal drawn implements in 2000. Rice varietal changes were found in 2018 wet season. Moreover, the respondents changed to use certified seeds from farm saved seeds in dry season. Regarding with varietal information, most of the respondents received it from other farmers in 2000, while 50% of respondents changed to obtain it from DOA in 2018. The crop establishment method was not changed in both wet and dry seasons, and consequently increased in use of family (2 and 2 person $ha^{-1}$ for wet (transplanting) and 1 and 2 person $ha^{-1}$ (broadcasting) for dry seasons and hired labours (14 and 16 person $ha^{-1}$) for wet and (1 and 2 person $ha^{-1}$ ) for dry seasons. Not only applications of chemical fertilizers but also amount of fertilizers (18.9 N kg $ha^{-1}$, 5.6 P kg $ha^{-1}$ and 5.4 K kg $ha^{-1}$) for wet and (113.3 N kg $ha^{-1}$, 24.8 P kg $ha^{-1}$ and 18.9 K kg $ha^{-1}$ ) for dry seasons were increased in both seasons of 2018. Pest and diseases control was not practiced in 2000 but nearly 80% of respondents used agro-chemicals in 2018. Most of the respondents still did not practice weed control in wet season, however, 60% of the respondents changed to use chemical herbicides in dry season, 2018. Nearly all respondents changed to use combine harvester for dry season harvest, although manual harvesting method was still practiced in wet season. In wet season, half of the respondents threshed their harvested rice by cattle trampling and the rest used thresher in 2000, but in 2018, all of them changed to use mechanical thresher. Better price and good eating quality induced the changes of Paw San rice variety in place of Hnangar at wet season. Management practices were changed due to intervention of extension activities by DOA on utilization of quality seeds, split fertilizer applications, pesticide and herbicide applications. High demand on labour at peak season and scarcity of labour led to change from traditional method to mechanization in the study area.

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# CHAPTER I
# INTRODUCTION

Rice is the world's single most important foodstuff as well as the staple food for over the billion of people in most of the countries. It is an important and nutritionally vital food commodity that feeds more than half of the world's population (Verma & Shukla, 2011). Moreover, rice is accounting for about 93 percent of the total food produced, about 70 percent of average calorie intake and 35 percent household expenses. Rice production is the largest provider to farm income, while associated trade and business are important sources of rural non-farm income (Ahmed, 2001). It is grown on nearly 146 million hectares, more than 10 percent of total cultivated land. Therefore, total world rice production is about 535 million tons. Ninety seven percent of the world's rice is grown by developing countries, mostly in Asia (International Rice Research Institute [IRRI], 1997). In addition, 89 percent of the world's harvested rice was grown by Asian farmers accounting for 91 percent of global rice production (Lantin, 1999). Rice serves as the most important food source for Asian countries mainly in south-east parts where it is an economic crop for farmers and workers who grow it on millions of hectares throughout the region (Gomez, 2001).

In Myanmar, rice is important in national and international trades with political and social implications. Concerning with food crop production in Myanmar, actual rice sown area in 2017-2018 was 7.26 million hectares with the average yield of 3.92 metric tons $ha^{-1}$ and production was reached at 28.46 million metric tons, rice is self-sufficient and thus exporting surplus of rice approximately more than a million ton every year (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018a).

In Myanmar, rice is grown during the monsoon and summer seasons in four growing zones: the delta, dry zone, coastal zone, and mountainous areas. About 80% of the annual production is harvested during the monsoon season and the remaining 20% during the summer season. About 50% of the total production comes from the delta comprised of the Ayeyarwaddy, Bago and Yangon regions. About 25% is produced in the dry zone, including Mandalay, Sagaing, and Magway Regions (United States Department of Agriculture [USDA], 2016).

Rice production in the Ayeyarwaddy Region is vitally important for the production of high-quality fragrant rice for both domestic consumption and export. The majority of rice production of Ayeyarwaddy Region contributed about 24.42% of the total rice sown areas in 2006-2007. In this Region, total rice sown areas were increased from

0.52 million hectares in 1989-1990 to 1.98 million hectares in 2006-2007 that comprised of 1.48 million hectares of monsoon paddy and 0.5 million hectares of summer paddy, respectively. Yield per hectare was also increased from 3.25 ton $ha^{-1}$ in 1989-1990 to 4.10 ton $ha^{-1}$ in 2006-2007. Therefore, rice production was increased from 1705.09 thousand tons in 1989-1990 to 8161.92 thousand tons in 2006-2007 (Ministry of Agriculture and Irrigation [MOAI], 2008).

Rice production in the delta increased significantly from 1976 to 1988 with the implementation of the Paddy Land Development Projects 1 and 2 by the World Bank and the Asian Development Bank (Driel & Nauta, 2013). LIFT project is one of the development organization involved in the seed sector development in the Delta. LIFT partners include IRRI, Radanar Ayar Rural Development Association, Metta Development Foundation and Mercy Corps. Beside these JICA, ACIAR and FAO, in complementarily to LIFT investment, have been involved in supporting seed production and dissemination projects (Livelihoods and Food Security Trust Fund [LIFT], 2017).

The Ayeyarwaddy Delta has been a gradual expansion of its area under irrigation in order to intensify the crop production. The irrigated area has increased substantially from 1.02 ha in 1988 (12.6% of the net sown area) to 2.17 million ha in 2013-2014 (16.3% of the net sown area) (MOAI, 2014a). Total rice sown areas were increased from 1.9 million hectare in 2000-2001 to 2.1 million hectare in 2017-2018 that comprised of 1.5 million hectare of monsoon rice area and 0.6 million hectare of summer rice area, respectively. Yield per hectare was also increased from 3 ton $ha^{-1}$ in 2000-2001 to 3.8 ton $ha^{-1}$ in 2017-2018. Rice production was increased from 6 million tons in 2000-2001 to 8 million tons in 2017-2018 (MOALI, 2018b).

Significantly, in recent years, climate change shocked rice production of Ayeyarwaddy delta. The most prominent changes were the late onset and early withdrawn of monsoon which shorten the duration of monsoon relative to the regular period. In combination with heavy monsoon rainfall, rising sea levels created serious water logging and prolonged stagnant floods in the low-lying areas of Ayeyarwaddy delta damaging the thousand acres of rice fields (Htway, Phyo, Grünbühel & Williams, 2014).

Therefore, it is needed to study the changes of rice production system in Ayeyarwaddy delta. The objective of the study was

- to investigate the changes of rice production system between 2000 and 2018 in Mawlamyinegyunn Township

# CHAPTER II
# LITERATURE REVIEW

## 2.1 Importance of Rice

Rice is a major staple food and a mainstay for the rural population and for household food security. It is mainly cultivated by small farmers in holdings of less than one hectare. Rice also plays an important role as a “wage” commodity for workers in the cash crop or non-agricultural sectors. It plays a pivotal role for the food security of over half of the world population. It is also a central component of the culture of a number of communities. For those reasons, rice is considered as a “strategic” commodity in many countries, both developed and developing (Caple, 2006).

There are only two major species of cultivated rice: *Oryza sativa*, or Asian rice, and *Oryza glaberrima*, or African rice. Rice can be produced under a wide spectrum of locations and climates, but, geographically, Asia is the hub of 90 percent of world production, with China and India responsible for 30 percent and 21 percent, respectively of the world aggregate (Food and Agriculture Organization of the United Nations [FAO], 2006).

Rice (*Oryza spp.*) is an economically important crop in the world (Odjo, Dossou, Dansi, Bonou & Kombate, 2017). And also, rice is one of the most important crops globally for food production, supporting livelihoods and its role in global biogeochemical processes. Rice agriculture faces major challenges in the coming decade because of increasing resource pressures, severe weather and climate change, population growth and shifting diets, and economic development. Nowadays, the majority of rice in world market is grown in South and Southeast Asia (India, China, Indonesia, Bangladesh, Thailand, Vietnam, Myanmar, Philippines). The world average consumption of rice in 1999 was 58 kg, with the highest intake in some Asian countries; Myanmar has the highest annual consumption at 211 kg per person. Asia accounted for 60% of the global population, about 92% of the world’s rice production, and 90% of global rice consumption (IRRI, 2007).

Seventy percent of the rural population of Myanmar engages in rice farming for their livelihood; rice is thus our life, our economics, and our politics. It is vital to keeping peace and tranquility in the country. Agriculture is the main source of livelihood of the Myanmar people. Rice is the major agriculture commodity grown in almost 50% of the cultivated area. The Ayeyarwaddy delta, central dry zone, Yangon deltaic, and Rakhine coastal areas are the major rice producing eco-physiographic regions (MOAI, 2015).

## 2.2 Rice Production and Export of Myanmar

Myanmar, formerly Burma, the second largest country of Southeast Asia, is located between 9°58′N to 28°31′N and 92°9′E to 101°10′E. The population of the country was approximating 51.7 million in 2014, and is increasing at an annual rate of 1.01%. At present about 70% of Myanmar's population are rural dwellers whose livelihoods depend on farming. The agricultural sector contributes 22.1% to the GDP, 20% to the total export earnings and it employs 61.2% of the labour force. Rice is by far the most important crop and is grown in areas categorized as rainfed, irrigated and upland, occupying 48%, 20% and 3% of the total sown areas, respectively (MOAI, 2014b).

Myanmar's rice-growing areas can be categorized into two agro-ecosystems namely, favorable lowlands, which account for 68% of the 7.59 million hectare sown area in 2012-2013, and unfavorable rainfed, which comprises 32% of the rice areas. These two agro-ecosystems are further divided into seven rice sub-ecosystems. The favorable lowland is comprised of the rainfed lowlands (48%) and irrigated lowlands (20%). The unfavorable rainfed area is subdivided as drought prone, deep-water, submerged, salt affected and uplands (Department of Agriculture [DOA], 2013).

Rice production is central to the economy and food security of Myanmar. Between 1900 and 1940, Myanmar exported 2 to 3 million metric tons of rice annually, up to 70% of national production (Win, 1991). Ward, Smith and Tran (2016) identified that nine intervention areas in the rice production cycle where improvements in productivity and profitability can be achieved. Each of these intervention areas has relevance to both the rain fed lowland and irrigated rice systems. There areas were (1) seed selection, (2) land preparation, (3) crop establishment, (4) water management, (5) soil fertility management, (6) pest management, (7) harvesting and threshing, (8) drying and storage and (9) crop rotation.

Rice production is forecast to increase to 13.2 million metric tons in Myanmar 2017/2018 from 12.65 million metric tons in 2016/2017 mainly due to favorable weather and the expectation of more irrigated water being provided for farmers. In Myanmar 2018/2019, rice production is forecast to rebound to 13.4 million metric tons in anticipation of more price incentives, utilization of high yielding seeds, greater farm mechanization, and replacement of rice for pulses are due to low pulse prices resulting from an Indian pulse import ban in August 2017. Growth will also be propelled by robust rice export demand and more loans for Agricultural related small and median enterprise (SME) in 2018.

Rice accounts for the largest area of crops grown in Myanmar, about 8 million hectares, or 34% of the total (planted) cropped areas of 23.5 million hectares in Fiscal Year (FY) 2010. Rice production has increased considerably since the introduction of high-yielding varieties in the late 1970s and the expansion of double cropping of summer rice since 1992. Between FY 1990 and FY 2010, the area harvested increased from 4.76 million hectares to 8.01 million hectares, or 68%. Rice production increased from 13.7 million metric tons (MMT) to 32.1 million metric tons in the same period, a rise of 134%; and rice yield from 2.9 ton $ha^{-1}$ to 4 ton $ha^{-1}$, a rise of 38%. A decomposition of the factors contributing to production increases shows that area growth contributed 58% and yield growth 42%. For FY 2010, self-sufficiency based on total utilization (that is, adjusting for seeds and losses) is estimated to be 147%. According to a Myanmar Rice Federations estimate, total production of milled rice is about 14-15 million metric tons, with domestic consumption of 11-13 million metric tons. This translates into a 2-3 million metric tons exportable surplus, which is captured as normal exports via ports as well as both formal border posts established by the Ministry of Commerce and illegal border trade (Wong & Wai, 2013).

Before World War II (1921-1941) Myanmar was the largest rice exporting country in the world. After gaining independence considerable attention was given to increasing rice productivity but Myanmar's role in the world rice market declined after the 1960s (Dawe, 2002). From 1977/1978 to 1985/1986, the Whole Township Rice Production Program, as a part of the Green Revolution, through the High-Yielding Program was implemented to increase rice production by the introduction of modern rice varieties in combination with improved production technologies. As a result of this program, rice yields increased from 1.8 to 3.1 ton $ha^{-1}$ during that period. Despite continuing efforts of the Myanmar government and farmers, the national average yield is still stagnating within 3 to 4 ton $ha^{-1}$ (MOAI, 2015).

During the 1930s, Myanmar was the world's largest rice exporter at about 3 million tons annually. Exports considerably reduced after the 1930s and nearly vanished in the 1970s. Market liberalization in the late 1980s led to the lifting of the ban on private exports in 1988; in 2004 export of rice was again privatized. Rice exports started to expand after the liberalization of domestic and international markets in 2003 and by 2013/2014 it had reached 1.6 million tons, the highest level in 40 years. The government set target of rice exports of 2 million tons a year by 2015 and 4 million tons by 2020. However, the quality and price of the rice exported from Myanmar remain lower than the

international market even as world demand for aromatic rice has increased as a result of the preference for high quality rice of high-income consumers. At present, the price of aromatic rice is more than double the price of normal white rice but the share of aromatic rice exporters in the world market remains small. In Southeast Asia, Thailand used to be the sole exporter of Jasmine rice. Recently, however, Vietnam and Cambodia have emerged as important exporters, Vietnam since 2007 and Cambodia beginning 2013 (Myint & Napasintuwong, 2016).

### 2.3 Rice Production in Delta Region

In Myanmar, Ayeyarwaddy Delta is one of the most important agricultural regions in the country. Ayeyarwaddy Delta contributed over 30% of the national rice production, and the total rice sown area of Ayeyarwaddy Delta was more than 25% of total national rice sown areas in 2007-2008. In terms of summer rice cultivation, almost 80% was grown in Ayeyarwaddy Delta. It is also a dynamic area with increasing investment in the agricultural sector. Although the Delta is not the area with the highest poverty rate in Myanmar, it can still be categorized in the high range because the prevalence of poverty shows 26%. Particularly noteworthy are high concentrations of landlessness (32.6%) in the Delta (Htway et al., 2014).

Ayeyarwaddy delta, one of the Asian mega deltas, is famous as the rice bowl of Myanmar as it occupies 26% of total rice growing area (7,706,526 ha) of the country. Deltas are important for global food security since rice is intensively cultivated in its alluvial fertile land. More than 80% of the world's total area of rice comes from deltaic lowlands of Asia. Lowland rice farming is the major livelihood activity for the farmers in the Ayeyarwaddy Delta. Crop types depend on soil type and water availability. If irrigation is available, the farmers practice double/triple cropping. Rice is the main crop for Ayeyarwaddy delta Region, though, locally, some farmers prefer pulses and oilseed crops following rice (Htway et al., 2014).

Myanmar's delta region is both a vital center of agricultural production and home consumption to nearly 40% of its total population. Yet, despite decades of investments and policy reforms, poverty rates remain high amongst its predominantly rural (85%) population, largely engaged in agriculturally-based livelihoods. The region generally enjoys many geographic advantages for agriculture compared to other areas in Myanmar. It receives significant rainfall, hosts a labyrinth of waterways, features generally fertile and rich soil, level terrain, and a diverse aquatic ecosystem. The Ayeyarwaddy delta is

home to 21 million people, with the majority depending on rice production for livelihood. The average farm size per household is about 4.5 ha, which is the largest in the country. However, the delta is also the place of many landless people with low levels of income (Driel & Nauta, 2013).

The harvested rice area in Ayeyarwaddy delta was increasing at a low rate from 1.9 million ha in 2000-2001 to 2 million hectare in 2010-2011. Similarly rice production increased from 6 million metric tons in 2000-2001 to 8.5 million metric tons in 2010-2011. Starting 2011-2012, harvested area and production was decreasing at a low rate and then increasing in 2017-2018 (MOALI, 2018b) (Table 2.1).

Large areas of the delta are subjected to flooding ranging in duration from a few days to 2 or 3 months, presenting significant risks to farmers. Some areas, though declining in importance, are suitable for deepwater rice, a low yielding rice type that elongates to stay above the rising water. Other varieties, including a new variety carrying the Sub1 gene (Bailey-Serres et al., 2010), demonstrate adaptation to periods of total submergence, a potentially valuable trait as more frequent and prolonged submergence events may be a consequence of climate change. Without the benefit of submergence tolerance, excessive flooding severely limits the scope for using improved high yielding varieties and crop management. Another relatively minor system involves transplanting of rice as floodwater recedes after the monsoon season, with subsequent irrigation from the receding water.

Cyclone Nargis made landfall on Myanmar on May, 2008. The severe tropical storm hit the Ayeyarwaddy Delta Region and the country's largest city, Yangon, causing catastrophic destruction and at least 138,000 fatalities. The storm impacted the most populous area of the country, as well as one of the most productive regions. Rice production has been essential to the food security of most Myanmar, which was already a serious situation prior to the cyclone. The cyclone hit during the first rice harvest of the year, though most rice had been harvested, the cyclone destroyed crops that had not yet been harvested and crops that were being stored (FAO, 2011).

Cyclone Nargis hit Myanmar in the first few days in May and impacted farmers in the final stages of their 2008 dry season harvest. As a result, much of this harvest was destroyed or damaged as the cyclone and the subsequent storm surges hit. This meant that small-scale farmers were unable to fully repay the loans borrowed in late 2007 and subsequently experienced difficulty in accessing credit to finance their 2008 wet season crop. Small-scale farmers and mid-scale farmers alike sustained losses to seeds, farming

equipment and animals, which contributed to drastically reduced crop yields in the 2008 wet season. The wet season harvest in the Ayeyarwaddy cyclone-affected areas was 32% lower than the previous year (Bose, 2009).

### 2.4 Monsoon and Summer Seasons of Rice Production

Rice is grown in Myanmar during the monsoon (June to November) and summer (December to May) seasons. There are two dominant rice production systems: rainfed lowland and irrigated lowland. During the monsoon season, Myanmar's rainfall in the delta and coastal region is sufficient for growing rice without supplemental irrigation from dams, river and stream diversions or groundwater. Where available irrigation together with drainage structures, improves stability of production and reduces the risks of flooding and stagnant water (Denning, Baroang & Sandar, 2013).

Rice can be grown twice a year in areas where irrigation is available. The monsoon (rainfed) crop is far more important in terms of area than the irrigated secondary (summer) crop. Nevertheless, secondary (summer) crop yields are usually higher than those of the monsoon crop because of better soil-moisture control under irrigation. Overall, about 85% of the annual rice production is grown during the monsoon and 15% during the secondary summer season. Rice is mostly transplanted in both seasons. Average rice yields in Myanmar (generally between 3.8 and 4.7 ton $ha^{-1}$) are similar to those achieved in Thailand but are significantly lower than in Vietnam (5.8 ton $ha^{-1}$) and China (6.9 ton $ha^{-1}$) (Goodbody, Kurbanova, Coslet & Wise, 2016).

Rice double cropping, or the so-called summer rice program, was introduced in 1992, supported generously with irrigation and other services. Farmers were under a strict government request to grow rice in the summer season wherever irrigation facilities were provided. But the record showed that despite higher yields the areas under summer rice have not increased notably in the past 10-15 years. Between FY 2000 and FY 2010, the total rice-cropped area increased by 1.71 million hectares, of which 91% was accounted for by monsoon rice. In this period, the summer rice area only increased from 1.1 million hectares to 1.25 million hectares, while the monsoon rice area grew from 5.2 million hectares to 6.76 million hectares. On the other hand, the yield rate of summer rice grew faster because almost 100% of this rice was planted with high-yielding varieties, while the coverage of these varieties was only 60% for monsoon rice over this period (Wong & Wai, 2013).

**Table 2.1 Harvest area and production of rice in Ayeyarwaddy Delta (2000-2018)**

| Year | Harvest area (million ha) | Production (million MT) |
|---|---|---|
| 2000-2001 | 1.99 | 6.03 |
| 2001-2002 | 1.99 | 5.97 |
| 2002-2003 | 1.83 | 5.66 |
| 2003-2004 | 1.90 | 7.24 |
| 2004-2005 | 1.80 | 7.05 |
| 2005-2006 | 1.90 | 7.75 |
| 2006-2007 | 2.00 | 7.99 |
| 2007-2008 | 2.00 | 8.16 |
| 2008-2009 | 2.00 | 8.38 |
| 2009-2010 | 2.00 | 8.51 |
| 2010-2011 | 2.00 | 8.48 |
| 2011-2012 | 1.90 | 7.03 |
| 2012-2013 | 1.90 | 7.14 |
| 2013-2014 | 2.00 | 7.47 |
| 2014-2015 | 2.00 | 7.81 |
| 2015-2016 | 1.90 | 7.71 |
| 2016-2017 | 2.00 | 7.71 |
| 2017-2018 | 2.00 | 7.96 |

Source: Ministry of Agriculture, Livestock and Irrigation, (MOALI, 2018b)

## 2.5 Local Rice Varieties

Local varieties are valuable as they possess a huge treasure of genetic material for development and improvement programs (Odjo et al., 2017). They are adapted to local growing conditions. Local crop does well in a particular region because it has qualities that help it survive the conditions it faces there. Therefore, the local crop varieties from their areas are suitable for local temperature, rainfall and soil conditions of their relevant area. They also tolerate to common local pests well. Many local rice varieties are surely synonymous. Different names are given to the same variety in different localities. Some 2000 rice varieties have been recorded in Myanmar. They entered market-oriented agriculture; mixed varieties that differ in shape, size, and hardness of grain caused inefficient milling and produced inferior products. There were many rice varieties in the country. Although identical of rice varieties, farmers called as different names in different localities (Win, 1991). Most traditional rice varieties in the tropics are tall, sensitive to photoperiod and have long maturity periods. When they applied high levels of nitrogen, they tend to lodge at later growth stages. And then, their grain yields are extremely low. When these varieties are planted later than usual, they have shorter growth duration and usually are shorter in height, and consequently, have increased lodging resistance (Yoshida, 1981).

Today in Myanmar, the price differential between traditional local varieties and modern “IRRI-type” varieties is large. Paw San Yin, a fragrant variety produced in the delta, can fetch double the price of higher yielding semi-dwarf types. Trading by individual varietal names has increased since the 1990s (Okamoto, 2005).

Modern rice varieties (also known as high yielding varieties) are variously reported to be used for 70-80% of the monsoon crop and for virtually all the summer crop. Fang et al. (2009) stated that farmers often prefer local varieties during the monsoon season, especially in areas that are subjected to flooding. Local varieties, such as Paw San Yin 30, are typically of higher eating quality and bring as much as double the price of the HYVs. HYVs are widely grown in the summer season because of their early maturity and the absence of flooding risk at that time of year. Nationwide, HYV adoption has been reported as 61%, with highest level of adoption in the dry zone. According to the technology package with 10 impact points for high yielding rice production, Myanmar Agriculture Services (MAS) have been undertaken in 1975-1976.

**Technology Package with 10 Impact Points are:**

1. Applying and selection of high yielding rice varieties
2. Deep ploughing and harrowing for land preparation
3. Transplanting 25-30 days old seedlings
4. Fulfillment to plant population $acre^{-1}$
5. Applying recommended rate of fertilizers
6. Using cow dung and compost manures as basal fertilizers
7. Controlling of weeds
8. Management and control of pests and diseases
9. Irrigation and drainage regularly
10. Harvesting to reduce minimum waste

## 2.6 Rice Production Changes in Other Countries

Rice production occurs over vast areas of the world, particularly in Asia where it is a staple crop and has significant cultural and historical roots. Economically sound rice production requires particular agronomic requirements, such as a plentiful supply of water applied in a timely fashion (via rain or irrigation from groundwater or surface water sources), high average temperatures during the growing season, a smooth land surface to facilitate uniform flooding and drainage, and a subsoil hardpan that inhibits the percolation of water. Therefore, rice production in the United States is limited to certain areas (McBride, 2018).

Rice production in China has more than tripled in the past five decades, mainly due to increased grain yield rather than increased planting area (Peng, Tan & Zou, 2009). Institutional change (Lin, 1992), the use of modern varieties (Lin, 1994), fertilizers and pesticides (Huang & Rozelle, 1996) are the main reasons underlying agricultural growth between the 1980s and 1990s. However, rice yields appear to have stagnated over the past decade. Peng et al. (2009) showed that a narrow genetic base, overuse of fertilizers and pesticides, breakdown of irrigation infrastructure, oversimplified crop management and a weak extension system were the major problems facing rice production.

Rice production in Thailand has been changing continuously from the beginning of the Green Revolution in the 1960s. Key changes occurred with the development of the irrigation system especially in the Central Plain region, called the zone of Chao Phraya Project. With irrigation, the modern rice varieties (MVs) became widely adopted because of their high yield performance, high response to fertilizer in irrigated environment, and

early maturity. The latter characteristics has allowed farmers to cultivate two to three crops a year, increasing the demand for hired labor as a consequence of higher cropping intensity. The adoption of MVs in Thailand over the past few decades has also driven many changes in rice production. These included the application of new technologies, use of chemical fertilizers, and adoption of new rice varieties that are non-photoperiod sensitive. This enabled farmers to obtain a higher average rice yield in the wet season, from 267 kg $rai^{-1}$ in 1971-1975 to 370 kg $rai^{-1}$ in 2006-2010, and in the dry season, from 514 kg $rai^{-1}$ in 1971-1975 to 674 kg $rai^{-1}$ in 2006-2010. At present, the average rice yield per rai has nearly reached the maximum point under the present technology of production. Increasing rice yield per rai under the present technology could be achieved by improving the socio-economic characteristics and production management of farmers (Songsrirod, 2007).

Philippine rice production tripled from 5 million tons in 1970 to more than 16 million tons in 2008, with only a 44% increase in the area harvested. Instrumental to this development was the use of the Green Revolution's seed-fertilizer technology and access to irrigation facilities, which doubled the yield $ha^{-1}$ in the same period. Production gains fed the rapidly growing population and its increasing per-capita rice consumption. Except for a few years in the late 1970s and early 1980s, rice imports were used to fill the gap between demand and supply and to stabilize the domestic price of rice.

Rice production in the Philippines has increased significantly since 2001. The growth in output in this period was supported by the greater use of non-conventional inputs such as irrigation, hybrid rice varieties, and farmers' training. This implies that increasing farmers' access to these factors can further increase the total rice production in the country (Bordey, 2010).

# CHAPTER III
# RESEARCH METHODOLOGY

## 3.1 General Description of the Study Area

Ayeyarwaddy Region has the largest rice production area and is named as "**rice bowl**" of Myanmar. Ayeyarwaddy Region represents the general situation of the lower Myanmar in terms of geographic and socioeconomic conditions as well as rice farming practices. Mawlamyinegyunn Township is one of the major rice producing area in Laputta District, Ayeyarwaddy Delta of Myanmar. Laputta District is a district of the Ayeyarwaddy Region in south western Myanmar. It contains 4 townships: Laputta, Mawlamyinegyunn, Kyonmanage and Pyinsalu.

Mawlamyinegyunn Township is located between 16°23′N latitude and 95°16′E longitude. It covers around 1217 $km^2$ and there are 108 village tracts and 504 villages in this township. Total population of the township was 311,340 with 153,127 males and 158, 21 females. In this township, urban and rural total populations were 32,915 and 278,425, respectively (Department of Population, 2015).

### 3.1.1 Climate statistics

The climate of Mawlamyinegyunn Township is humidity with an average temperature of 27˚C and about 2633 millimeter of annual precipitation. Rainfall data from Department of Agriculture in Mawlamyinegyunn Township were recorded from 2009 to 2018. Among these years, the highest total precipitation was 2898.7 millimeter in 2016 and the lowest total precipitation was 2085.6 millimeter in 2010 (Figure 3.1). According to temperature data recorded from 2012 to 2018, the average minimum temperature and average maximum temperature were 20˚C in 2017 and 35˚C in 2016 (Figure 3.2).

## 3.2 Cultivated Area and Production of Rice in Mawlamyinegyunn Township

Mawlamyinegyunn Township is producing monsoon and summer rice. The cultivated area and production of rice are shown in (Table 3.1 and 3.2). The total land area of this township is 100846.8 hectares (ha) with 54,610 hectares of irrigated area and 46,236.8 hectares of non-irrigated area.

**Table 3.1 Cultivated areas (ha) of rice in Mawlamyinegyunn Township (2008-2018)**

| No. | Years | Rice cultivated area (ha) | |
|---|---|---|---|
| | | (monsoon season) | (summer season) |
| 1 | 2008-2009 | 78379 | 35644 |
| 2 | 2009-2010 | 78379 | 36031 |
| 3 | 2010-2011 | 88697 | 36803 |
| 4 | 2011-2012 | 88697 | 33572 |
| 5 | 2012-2013 | 88700 | 37981 |
| 6 | 2013-2014 | 88702 | 48604 |
| 7 | 2014-2015 | 88702 | 51438 |
| 8 | 2015-2016 | 88702 | 51840 |
| 9 | 2016-2017 | 100693 | 52004 |
| 10 | 2017-2018 | 100847 | 54610 |

Source: Department of Agriculture [DOA], 2018

**Table 3.2 Production (MT) of rice in Mawlamyinegyunn Township (2008-2018)**

| No. | Years | Rice production (MT) | |
|---|---|---|---|
| | | (monsoon season) | (summer season) |
| 1 | 2008-2009 | 305861.1 | 181291.1 |
| 2 | 2009-2010 | 307013.3 | 183334.7 |
| 3 | 2010-2011 | 347753.6 | 187285.0 |
| 4 | 2011-2012 | 314458.9 | 161386.5 |
| 5 | 2012-2013 | 305995.1 | 186340.5 |
| 6 | 2013-2014 | 308008.6 | 245348.9 |
| 7 | 2014-2015 | 319553.9 | 258302.4 |
| 8 | 2015-2016 | 321881.8 | 260865.4 |
| 9 | 2016-2017 | 365816.9 | 260026.6 |
| 10 | 2017-2018 | 363940.9 | 277012.9 |

Source: Department of Agriculture [DOA], 2018

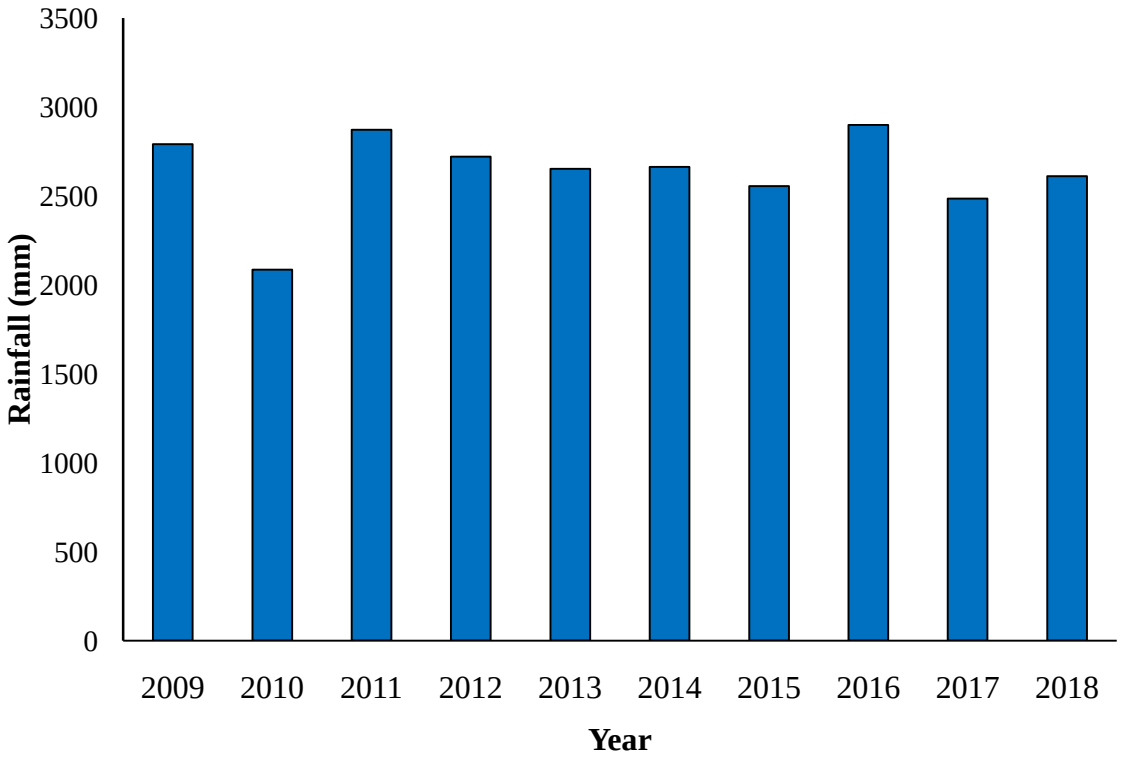


**Figure 3.1 Annual rainfall of Mawlamyinegyunn Township from 2009 to 2018 (DOA, 2018)**

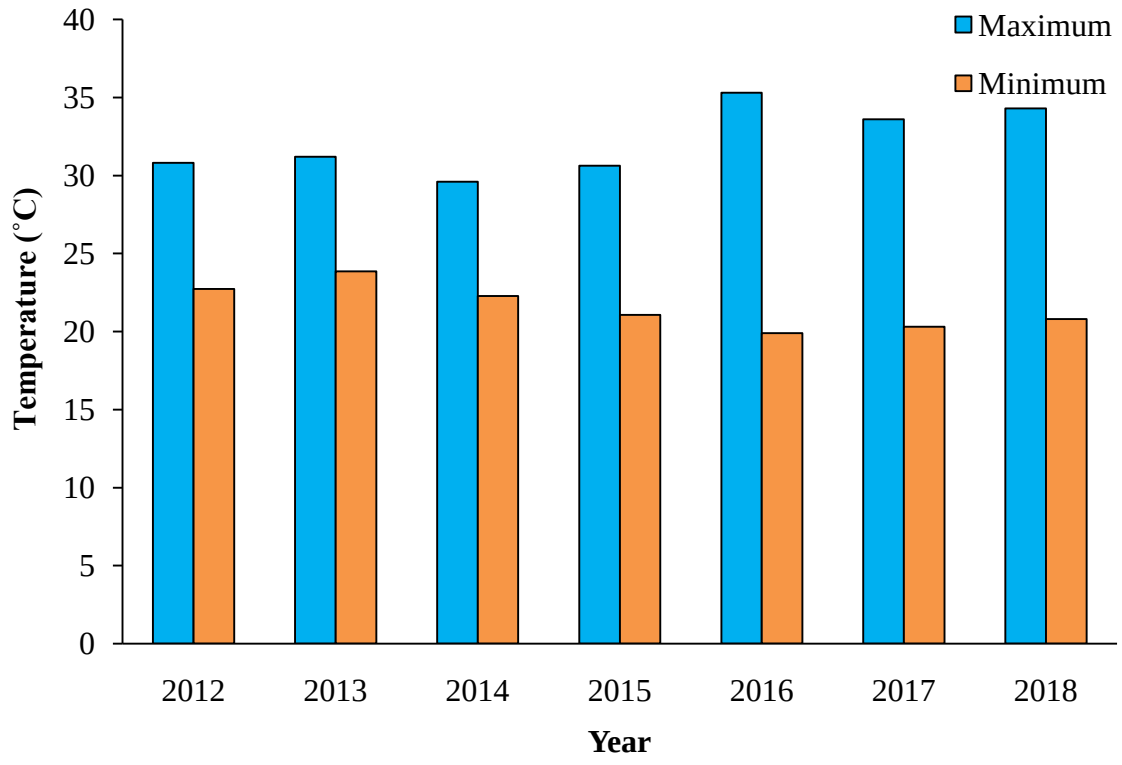


**Figure 3.2 Average maximum and minimum temperature of Mawlamyinegyunn Township from 2012 to 2018 (DOA, 2018)**

### 3.3 Sampling Method and Data Collection

In Ayeyarwaddy region, Mawlamyinegyunn Township was selected according to the area of rice cultivation. There are 108 village tracts. Among them, four village tracts were purposively selected to compare changes of rice production system between 2000 and 2018. A pre-test was done by interviewing ten percent of the total respondents to collect the information about the rice production changes between past and present at Mawlamyinegyunn Township in May 2018. The structured interview questionnaire was amended based on the information collected from the pre-test. Main research survey was conducted in October 2018. A purposive sampling method was adopted to select farm household heads for the questionnaire survey. The sample size from each village was 40 respondents and therefore a total of 160 sample farm households cultivating rice based farming were included in this study (Table 3.3).

Both primary and secondary data were used in this study. The primary data were collected from rice farmers with the structured interview questionnaire. Data were concerned with demographic data of the sample respondents in selected villages such as age, family size, labour and farm size. In addition, their major crops and changes of cultural practices such as use of cultivars (hybrid/high yielding/local), land preparation (draught animals/machinery), sowing time, sowing methods (direct seeded/transplanted), irrigation methods (intermitted/flooded), amounts and kinds of fertilizer (organic/ chemical), pest and diseases control, methods of weed control, methods of harvesting (manual or machinery), yield, use of rice straw residues, rice market, own consumption and climate threat for rice production were collected. The secondary data (climatic data, rice sown area, yield, etc) were obtained from Department of Agriculture (DOA), Mawlamyinegyunn Township.

### 3.4 Statistical Analysis

The data were encoded and entered into the Microsoft Excel Program. The data were transferred and analyzed by the Statistical Package for Social Science Program (SPSS) version 23 software. Descriptive analysis was used to explore the changes of rice production between 2000 and 2018. The paired-sample T Test was used to analyze the statistically differences of rice farming systems between 2000 and 2018. The chi-square test was used to analyze the group of differences for the comparison of rice production system between 2000 and 2018.

**Table 3.3 Number of respondents selected from the study area, 2018**

| No. | Village Tract | Villages | No. of respondents |
|---|---|---|---|
| 1 | Mayeownpinsu | Mayeownpinsu | 40 |
| 2 | Mazalepatheinsu | Goatchaung | 40 |
| 3 | Hteeparla | Latpansu | 40 |
| 4 | Kahnyinchaung | Kahnyinchaung | 40 |
| | Total | | 160 |

# CHAPTER IV
# RESULTS AND DISCUSSION

## 4.1 Results

### 4.1.1 Socio - economic characteristics of sample respondents

The results of the survey indicated that 24.4% of the respondents were in the young age group between 21 and 40 years. The respondents 47.5% were the age group of between 41 and 60 years while 27.5% of the respondents were between 61 and 80 years. (Table 4.1). Mean age of the sample respondent was 51 years; they still belonged to the somewhat older age group, which indicates that only older members of the group would like to continue rice farming. Rice farming was being mostly undertaken by older farmers.

Changes of total farm size of the sample respondents in Mawlamyinegyunn Township can be seen in (Table 4.2). Average farm sizes of sample respondents in past (2000) and present (2018) were 3.4 and 3.7 ha, respectively. Changes of total farm size of the sample respondents during 20 years were not significantly different (t= -1.21). In past, the highest percentage 43.8% of sample respondents possessed 2.1 to 4 ha and these sample respondents were decreased to 40.6% at present. The respondents 36.9% who owned 0.2 to 2 ha in the past and those respondents increased to 38.1% at present. There was no change of land possession of the respondents 4.1 to 6 ha. Five percent of the sample respondents possessed 6.1 to 8 ha in past whereas at present, these respondents decreased to 2.5%. The owners of larger farm size (>8 ha and 10 ha) were increased to 0.6 to 1.3% and 2.5 to 6.3%, respectively.

However, the changes of total farm size of respondents were significantly varied according to group of farm size they possessed ($\chi^2$=244.54). Few farmers possessed 0.2-2 ha in 2000 increasingly possessed to 2.1-4 ha (5%), 4.1-6 ha (8.5%) and 6.1-8 ha (1.7%), respectively in 2018. Similarly, the sample respondents who possessed 4.1 to 6 ha were decreased 0.2 to 2 ha (11.1%), 2.1- 4 ha (22.2%) whereas 11.1% of this group had owned over 10 ha. The owners of 6.1 to 8 ha land decreased to 0.2 to 2 ha (25%) and the possession of 12.5% each of respondents also decreased to 2.1 to 4 and 4.1 to 6 ha, 37.5% of them became owners of over 10 ha. Although 25% of respondents owned over 10 ha in past, but at present, these same percentages of respondents lost their land and possessed only 0.2 to 2 ha and 4.1 to 6 ha, respectively (Table 4.3).

**Table 4.1 Age group of respondents in Mawlamyinegyunn Township**

| Age group (years) | Respondents | |
|---|---|---|
| | Frequency | Percentage |
| 21-40 | 40 | 25.0 |
| 41-60 | 76 | 47.5 |
| 61-80 | 44 | 27.5 |
| Total | 160 | 100.0 |
| Mean | 51.4 | |

n=160

**Table 4.2 Total farm size of the respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Total farm size (ha) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 0.2-2 | 59 | 36.9 | 61 | 38.1 |
| 2.1-4 | 70 | 43.8 | 65 | 40.6 |
| 4.1-6 | 18 | 11.3 | 18 | 11.3 |
| 6.1-8 | 8 | 5.0 | 4 | 2.5 |
| 8.1-10 | 1 | 0.6 | 2 | 1.3 |
| over 10 | 4 | 2.5 | 10 | 6.3 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 3.4 | | 3.7 | |
| Minimum | 0.4 | | 0.4 | |
| Maximum | 16.0 | | 20.0 | |
| t value | $-1.21^{ns}$ | | | |

ns = non significant, n=160

**Table 4.3 Changes of total farm size owned by respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Total areas (ha) (2000) | Respondents | | | | | |
|---|---|---|---|---|---|---|
| | Total areas (ha) (2018) | | | | | |
| | **0.2-2** | **2.1-4** | **4.1-6** | **6.1-8** | **8.1-10** | **Over 10** |
| 0.2-2 | 50(84.7) | 3(5.1) | 5(8.5) | 1(1.7) | 0(0.0) | 0(0.0) |
| 2.1-4 | 6(8.6) | 57(81.4) | 3(4.3) | 1(1.4) | 0(0.0) | 3(4.3) |
| 4.1-6 | 2(11.1) | 4(22.2) | 8(44.4) | 1(5.6) | 1(5.6) | 2(11.1) |
| 6.1-8 | 2(25.0) | 1(12.5) | 1(12.5) | 1(12.5) | 0(0.0) | 3(37.5) |
| 8.1-10 | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 1(100.0) | 0(0.0) |
| Over 10 | 1(25.0) | 0(0.0) | 1(25.0) | 0(0.0) | 0(0.0) | 2(50.0) |
| $\chi^2$ | 244.54*** | | | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

### 4.1.2 Possession of farm size and composition

Average rice areas possessed by respondents were 3.3 and 3.6 ha in the past and present, respectively. Changes of total rice areas owned by sample respondents during 20 years were not significantly different (t = -1.51). The majority of the respondents 43.1% possessed 2.1 to 4 ha in past and that farm size of respondents decreased to 40.6% at present. Nearly the same percentages of respondents 38.8% owned 0.2 to 2 ha of rice area in the past and present. Ten percent of respondents possessed 4.1 to 6 ha of rice area in past and increased to 11.3%. The possession of respondents who owned 2.1-4 ha was decreased to 0.2-2 ha (8.6%) whereas the increase possession of 4.1-6 ha and 6.1-8 ha land was found in 4.3% and 1.4% of farmers. Moreover, 4.3% of this group's possession had changed to over 10 ha. Very few farmers owned > 6 ha of rice fields in 2000 and 2018 (not more than 5%) (Table 4.4).

However, the changes of rice areas owned by respondents were significantly varied according to group of rice areas they possessed ($\chi^2$=218.68). The owners of 0.2-2 ha land became the owners of 2.1-4 ha (8.1%), 4.1-6 ha (8.1%) and 6.1-8 ha (1.6%), respectively. Among rice land (2.1-4 ha) owners in 2000, the change was in decreasing trend because 7.2% of them possessed the smallest size of 0.2-2 ha rice land owners in 2018. The changes of rice farm size (4.1-6 ha) were found in both decreasing and decreasing trends because 12.5% each of those owners had possessed 2.1-4 ha and 0.2-2 ha, respectively in 2018. At the same time, the same percents of owners possessed larger size of rice lands (> 6 to 10 ha) (Table 4.5).

Average numbers of rice plots owned by respondents were 1.3 and 1.3 plots in past and present, respectively. Changing rice plots possessed by respondents during 20 years were not significantly different (t = -1.13). Majority of the respondents (95%) had 1-2 rice plots in past and the owners decreased to 93.1% at present. In the past, 3-4 rice plots were owned by the 5% of respondents, whereas at present the number of owners increased to 6.9%. Considering rice field locations, respondents 82.5% owned aggregated field plots in past while these percentages of respondents decreased to 79.4% at present. The respondents' rice field soil condition such as relief, soil texture and soil quality were not different in both past and present. Texture of their soil was clay and soil quality was medium level (Table 4.6).

**Table 4.4 Rice sown area of the respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice sown area (ha) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 0.2-2 | 62 | 38.8 | 61 | 38.1 |
| 2.1- 4 | 69 | 43.1 | 65 | 40.6 |
| 4.1- 6 | 16 | 10.0 | 18 | 11.3 |
| 6.1- 8 | 9 | 5.6 | 5 | 3.1 |
| 8.1-10 | 1 | 0.6 | 3 | 1.9 |
| over 10 | 3 | 1.9 | 8 | 5.0 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 3.3 | | 3.6 | |
| Minimum | 0.4 | | 0.4 | |
| Maximum | 16.0 | | 20.0 | |
| t value | $-1.51^{ns}$ | | | |

ns = non significant, n=160

**Table 4.5 Changes of rice sown area owned by respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice sown area (ha) (2000) | Respondents | | | | | |
|---|---|---|---|---|---|---|
| | Rice sown area (ha) (2018) | | | | | |
| | 0.2-2 | 2.1-4 | 4.1-6 | 6.1-8 | 8.1-10 | Over 10 |
| 0.2-2 | 51(82.3) | 5(8.1) | 5(8.1) | 1(1.6) | 0(0.0) | 0(0.0) |
| 2.1-4 | 5(7.2) | 57(82.6) | 3(4.3) | 1(1.4) | 0(0.0) | 3(4.3) |
| 4.1-6 | 2(12.5) | 2(12.5) | 8(50.0) | 1(6.3) | 1(6.3) | 2(12.5) |
| 6.1-8 | 2(22.2) | 1(11.1) | 1(11.1) | 2(22.2) | 1(11.1) | 2(22.2) |
| 8.1-10 | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 1(100.0) | 0(0.0) |
| Over 10 | 1(33.3) | 0(0.0) | 1(33.3) | 0(0.0) | 0(0.0) | 1(33.3) |
| $\chi^2$ | 218.68*** | | | | | |

Figures in the parentheses are percentages.
*** = significant at 1% level, n=160

**Table 4.6 Conditions of rice fields owned by the respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Conditions | Respondents | | | |
|---|---|---|---|---|
| | (2000) | (2018) | Mean | t value |
| **1. No. of plot /farmer** | | | | |
| 1-2 | 152(95%) | 149(93.1%) | 1.3 | -1.13$^{ns}$ |
| 3- 4 | 8(5%) | 11(6.9%) | | |
| Total | 160(100%) | 160(100%) | | |
| **2. Composition** | | | | |
| Aggregated fields | 132(82.5%) | 127(79.4%) | | |
| Scattered fields | 28(17.5%) | 33(20.6%) | | |
| Total | 160(100%) | 160(100%) | | |

ns = non significant, n=160

### 4.1.3 Changes of cultural practices in wet and dry seasons

#### 4.1.3.1 Cropping pattern

In study area, most of the respondents (86.9%) grew rice after rice per year. However, 6.9% practiced rice-fallow and 6.3% cultivated rice-upland crop (maize, beans, onions, etc) in the past. However, at present, all respondents' cropping pattern was rice-rice. For 2000, 13.1% of sample respondents cultivated rice as mono crop but at present, all respondents planted rice as double cropping (Table 4.7).

Nearly all of the respondents about 93.1% cultivated rice for all of their land in the past and present. Food crops were planted by 4.4% of sample respondents in the past and decreased to 1.9% at present. A few percentages of sample respondents 2.5% sown perennial crops in the past and these crops were planted by 3.1% of the respondents at present. Only 1.3% of respondents cultivated non food crops (such as feed, energy, flowers) at present (Table 4.8).

#### 4.1.3.2 Seed selection

**Wet season**

All of the respondents used traditional rice varieties in 2000 wet season. Only 0.6% of sample respondent used improved variety at present. Because of good eating quality and price, the respondents grew traditional varieties in both past and present. All respondents cultivated long duration varieties in the past. However at present, long duration varieties were still used by 97.5% of the sample respondents and only 2.5% of respondents used medium duration varieties. Long duration varieties were the most suitable for wet season because they possessed taller heights which survive in deep water of the study areas. Most of the respondents 96.9% used non-certified seeds for wet season in the past and decreased to 81.3% at present. Certified seeds were used by only 3.1% of respondents in past and 18.8% of respondent used certified seed in present (Table 4.9).

The changes of seed type used by respondents for wet season were highly significantly varied according to group of seed type they accessed ($\chi^2$=22.37). The sample respondents (16.1%) have used non-certified seeds for wet season in 2000 and they changeably used certified seeds in 2018 (Table 4.10).

**Table 4.7 Rice based cropping pattern between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice based cropping pattern | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Rice-fallow | 11 | 6.9 | - | - |
| Rice-upland crop | 10 | 6.3 | - | - |
| Rice-rice | 139 | 86.8 | 160 | 100 |
| Total | 160 | 100.0 | 160 | 100 |

n=160

**Table 4.8 Other crops cultivated by respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Other crops | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Food crop | 7 | 4.4 | 3 | 1.9 |
| Rice | 149 | 93.1 | 150 | 93.8 |
| Perennials | 4 | 2.5 | 5 | 3.1 |
| Non food crop | - | - | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.9 Rice seeds used by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Variety** | | | | |
| Traditional | 160 | 100 | 159 | 99.4 |
| Improved | - | - | 1 | 0.6 |
| Total | 160 | 100 | 160 | 100.0 |
| **Life duration** | | | | |
| Long | 160 | 100 | 156 | 97.5 |
| Medium | - | - | 4 | 2.5 |
| Total | 160 | 100 | 160 | 100.0 |
| **Seed types** | | | | |
| Certified | 5 | 3.1 | 30 | 18.7 |
| Non- certified | 155 | 96.9 | 130 | 81.3 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.10 Changes of seed types used by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Seed types (2000) | Respondents | |
|---|---|---|
| | Seed types (2018) | |
| | Certified | Non-certified |
| Certified | 5(100.0) | 0(0.0) |
| Non-certified | 25(16.1) | 130(83.9) |
| $\chi^2$ | 22.37*** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

Although half of the respondents used their selected varieties due to easy access in their region in past, 2.4% of the respondents rejected this reason in present. Better price is one of the varietal preferences. Concerning better price, the reason for selection of rice variety is increased from 8.1% in past to 45% in present. The same percentages of respondents 26.3% used their selected varieties because of resistance to stress such as diseases and pest in both past and present. In past, 4.4% of respondents chose the varieties due to its better eating or cooking qualities and at present this reason increased to 13.8%. High yield is also one of the varieties preferences. Regarding with high yield, the reason for selection of variety increased from 9.4% in past to 10% in present. Only 2.5% of the respondents answered their reason of shorter duration in present (Table 4.11).

Changes of varietal preference of sample respondents for wet season were highly significantly varied according to group of their preference ($\chi^2$=80.51). Although majority of the sample respondents 95.1% used their selected varieties due to easy access in 2000, the reason of the respondents percentage changed to various reasons such as better price (52.5%) followed by better taste or cooking qualities (18.8%), resistance to stress (16.3%) and high yield (5%), shorter duration (2.5%) is in 2018. Respondents (23.1%) and (7.7%) used their chosen varieties because of better price in 2000 and in 2018, the reason of (23.1%) changed to resistance to stress such as pest and diseases and also (7.7%) changed to high yield. In 2000, (45.2%) of respondents used their chosen varieties because of resistance to stress and the reason of respondents percentages (31%) changed to better price and the same percentages (7.7%) changed to better taste or cooking qualities and high yield, respectively in 2018 (Table 4.12).

In wet season rice production, farmers mostly relied on fellow farmers and extensionists for varietal information. Most of the respondents (79.4%) obtained varietal information from fellow farmers in the past and decreased to 75.6% at present. Only 2.5% of sample respondents got varietal information from extensionists in the past and however, those respondents increased to 16.9% at present. Eighteen percent of sample respondents obtained varietal information by their own efforts (themselves) and these percentages decreased to 6.9% at present. Only 0.6% of the respondent got variety information from non-government organization (NGOs) at present (Table 4.13).

**Table 4.11 Varietal preferences for wet season of respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Varietal preference | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Available | 80 | 50.0 | 4 | 2.4 |
| Better price | 13 | 8.1 | 72 | 45.0 |
| Resistance to stress | 42 | 26.3 | 42 | 26.3 |
| Better taste | 7 | 4.4 | 22 | 13.8 |
| High yield | 15 | 9.4 | 16 | 10.0 |
| Shorter duration | - | - | 4 | 2.5 |
| Other reasons | 3 | 1.8 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.12 Changes of varietal preference for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Varietal preference (2000) | Respondents | | | | | |
|---|---|---|---|---|---|---|
| | Varietal preference (2018) | | | | | |
| | Available | Better price | Resistance to stress | Shorter duration | Better taste | High yield |
| Available | 4(5.0) | 42(52.5) | 13(16.3) | 2(2.5) | 15(18.8) | 4(5.0) |
| Better price | 0(0.0) | 9(69.2) | 3(23.1) | 0(0.0) | 0(0.0) | 1(7.7) |
| Other reasons | 0(0.0) | 1(33.3) | 1(33.3) | 0(0.0) | 0(0.0) | 1(33.3) |
| Resistance to stress | 0(0.0) | 13(31.0) | 23(54.8) | 0(0.0) | 3(7.1) | 3(7.1) |
| Better taste | 0(0.0) | 1(14.3) | 2 (28.6) | 0(0.0) | 4(57.1) | 0(0.0) |
| High yield | 0(0.0) | 6(40.0) | 0 (0.0) | 2(13.3) | 0(0.0) | 7(46.7) |
| $\chi^2$ | 80.51*** | | | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.13 Sources of varietal information for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Sources of varietal information | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Extensionist | 4 | 2.5 | 27 | 16.9 |
| Self | 29 | 18.1 | 11 | 6.9 |
| NGO | - | - | 1 | 0.6 |
| Fellow farmers | 127 | 79.4 | 121 | 75.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n = 160

The changes of varietal information obtained for wet season of sample respondents were highly significantly varied according to group of varietal information they obtained ($\chi^2$= 52.11). One fourth of the respondent got varietal information from extensionist in 2000 and they knew themselves in 2018. Although varietal information got by sample respondents 16.5% and 0.8% from fellow farmers in 2000, they obtained this information from extensionist and knew themselves in 2018. In 2000, (10.3%), (55.2%) and (3.4%) of the sample respondents knew themselves about variety information and they got from extensionist, fellow farmers and non-governmental organization, respectively in 2018 (Table 4.14).

**Dry season**

Most of the respondents (86.9%) used improved varieties for dry season and the rest of respondents could not grow dry season rice in the past. However at present, overall respondents used improved varieties for dry season. The respondents 31.3% cultivated medium duration varieties in dry season in the past and they were decreased to 11.3% at present. Shorter duration varieties were cultivated by 55.6% sample respondents in the past and at present, 88.8% of respondents planted these varieties. In study area, although most of the respondents 78.1% used non-certified seeds in the past and present, 46.3% and 53.8% of the respondents used non-certified seeds and certified seeds at present (Table 4.15).

There were highly significantly variation of respondents in changes of seed type for dry season according to group of seed type they used ($\chi^2$= 9.94). Although non-certified seeds were used by sample respondents 51.2% in 2000, 48.8% changed to use certified seeds in 2018. Only 7.1% of respondents used certified seeds in 2000 and changed to use non-certified seeds in 2018. Sample respondents who could not grow summer rice in 2000 however, they grew rice (42.9%) used certified seeds and non-certified seeds (57.1%) in 2018 (Table 4.16).

In 2000 dry season, the respondents used their selected varieties due to high yield potential (46.3%), easy access in their location (15%), having shorter duration (12.5%) and resistance to stress (11.9%). However, their preference on rice varieties were mainly changed to high yield with short duration (23.8%) and better price of variety (21.3%) (Table 4.17).

**Table 4.14 Changes the sources of varietal information for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Sources of varietal information (2000) | Respondents | | | |
|---|---|---|---|---|
| | Sources of varietal information (2018) | | | |
| | Extensionist | Fellow farmer | NGO | Self |
| Extensionist | 3(75.0) | 0(0.0) | 0(0.0) | 1(25.0) |
| No summer rice farmers | 21(16.5) | 105(82.7) | 0(0.0) | 1(0.8) |
| Self | 3(10.3) | 16(55.2) | 1(3.4) | 9(31.0) |
| $\chi^2$ | 52.11*** | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.15 Rice seeds used by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Variety** | | | | |
| Improved | 139 | 86.9 | 160 | 100 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100 |
| **Life duration** | | | | |
| Medium | 50 | 31.3 | 18 | 11.2 |
| Short | 89 | 55.6 | 142 | 88.8 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Seed types** | | | | |
| Certified | 14 | 8.8 | 86 | 53.7 |
| Non-certified | 125 | 78.1 | 74 | 46.3 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.16 Changes of seed types used by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Seed types (2000) | Respondents | |
|---|---|---|
| | Seed types (2018) | |
| | Certified | Non-certified |
| Certified | 13(92.9) | 1(7.1) |
| Non-certified | 64(51.2) | 61(48.8) |
| No summer rice farmers | 9(42.9) | 12(57.1) |
| $\chi^2$ | 9.94*** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.17 Varietal preferences for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Varietal preference | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Available | 24 | 15.0 | 1 | 0.6 |
| Better price | 1 | 0.6 | 34 | 21.3 |
| Resistance to stress | 19 | 11.9 | 8 | 5.0 |
| Shorter duration | 20 | 12.5 | 38 | 23.7 |
| Better taste | 1 | 0.6 | 1 | 0.6 |
| High yield | 74 | 46.3 | 78 | 48.8 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

Changes of varietal preference of sample respondents in dry season were not significantly varied according to group of variety preference they grown ($\chi^2$=39.79) but only a small group were varied. Although majority of the sample respondents (95.9%) used their selected varieties due to be easy access in 2000, the reason of the respondent's percentage changed to various reasons such as better price (29.2%) followed by better taste or cooking qualities (16.7%), and high yield (50%) in 2018. All farmers (100%) used their chosen varieties because of better price in 2000 and their reason of changing variety is high yield in 2018. Dry season rice could not grow by sample respondents (100%) in 2000 and their cultivated these season rice in 2018, among them, respondents (9.5%) used their selected varieties due to better price, resistance to stress (4.8%), shorter duration (19%) and high yield (66.7%). Sixty five percent of respondents used their chosen varieties due to shorter duration in 2000 and their reason changed to better price (35%), resistance to stress (5%) and high yield (25%) in 2018 (Table 4.18).

Most of the respondents (77.5%) relied varietal information from fellow farmers in 2000 whereas (48.8%) of the respondents got varietal information from extensionist at present. Only 48.1% of the respondents obtained varietal information from their friends and neighbors in 2018 (Table 4.19). The source of varietal information for dry season of respondents were highly significantly varied according to group of varietal information they obtained ($\chi^2$=41.11). All respondents who used extension for varietal information in 2000 have changed to extension source (90%) and fellow farmers (10%) respectively. Varietal information received by the respondents from fellow farmers were also changed their sources into extensionists (48.4%), fellow farmers (49.2%) and self orientation (1.6%), respectively. Although the sample respondents could not cultivate summer rice in 2000, they got varietal information from extensionists (28.6%) and fellow farmers (71.4%) in 2018 when they cultivated summer rice (Table 4.20).

#### 4.1.3.3 Land preparation

Most of the respondents (86.9%) did not use machine for land preparation in the past. Mechanical land preparation was done by 10.6% of the respondents using own tractor in 2000 and at present it was increasing done by 63.7% of respondents. Few respondents 2.5% hired tractor from private services for land preparation in the past and increased to 36.3% in present (Table 4.21).

Changes of land preparation were highly significantly varied according to group of mechanical land preparation they used ($\chi^2$=42.04). All respondents (100%) did not use machine for land preparation in 2000 and they changed to use machine in 2018. Among them 61.2% of respondents used own tractor and 38.8% hired tractor from private services for land preparation (Table 4.22).

**Table 4.18 Changes of varietal preference for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Varietal preference (2000) | Respondents | | | | | |
|---|---|---|---|---|---|---|
| | Varietal preference (2018) | | | | | |
| | Available | Better price | Resistance to stress | Shorter duration | Better taste | High yield |
| Available | 1(4.2) | 7(29.2) | 0(0.0) | 4(16.7) | 0(0.0) | 12(50.0) |
| Better price | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 1(100.0) |
| No summer rice farmers | 0(0.0) | 2(9.5) | 1(4.8) | 4(19.0) | 0(0.0) | 14(66.7) |
| Resistance to stress | 0(0.0) | 3(15.8) | 5(26.3) | 4(21.1) | 0(0.0) | 7(36.8) |
| Shorter duration | 0(0.0) | 7(35.0) | 1(5.0) | 7(35.0) | 0(0.0) | 5(25.0) |
| Better taste | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 0(0.0) | 1(100.0) |
| High yield | 0(0.0) | 15(20.3) | 1(1.4) | 19(25.7) | 1(1.4) | 38(51.4) |
| $\chi^2$ | $39.79^{ns}$ | | | | | |

Figures in the parentheses are percentages.

ns = non significant, n=160

**Table 4.19 Sources of varietal information for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Sources of varietal information | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Extensionist | 10 | 6.3 | 77 | 48.1 |
| Fellow farmer | 124 | 77.5 | 78 | 48.8 |
| Self | 5 | 3.1 | 4 | 2.5 |
| Private sector | - | - | 1 | 0.6 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.20 Changes the sources of varietal information for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Sources of varietal information (2000) | Respondents | | | |
|---|---|---|---|---|
| | Sources of varietal information (2018) | | | |
| | Extensionist | Fellow farmer | Self | Private sector |
| Extensionist | 9(90.0) | 1(10.0) | 0(0.0) | 0(0.0) |
| Fellow farmer | 60(48.4) | 61(49.2) | 2(1.6) | 1(0.8) |
| No summer rice farmers | 6(28.6) | 15(71.4) | 0(0.0) | 0(0.0) |
| Self | 2(40.0) | 1(20.0) | 2(40.0) | 0(0.0) |
| $\chi^2$ | 41.11*** | | | |

Figures in the parentheses are percentages.
*** = significant at 1% level, n=160

**Table 4.21 Land preparation implements between 2000 and 2018 in Mawlamyinegyunn Township**

| Animal / machine for land preparation | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Not mechanized/Animal | 139 | 86.9 | - | - |
| Own tractor | 17 | 10.6 | 102 | 63.7 |
| Hired tractor | 4 | 2.5 | 58 | 36.3 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.22 Changes for land preparation implements between 2000 and 2018 in Mawlamyinegyunn Township**

| Animal/machine (2000) | Respondents | |
|---|---|---|
| | Animal/machine (2018) | |
| | Own tractor | Hired tractor |
| Not mechanized/ Animal | 85(61.2) | 54(38.8) |
| Own tractor | 17(100.0) | 0(0.0) |
| Hired tractor | 0(0.0) | 4(100.0) |
| $\chi^2$ | 42.04*** | |

Figures in the parentheses are percentages.
*** = significant at 1% level, n=160

**Wet season**

More than half of the respondents (66.9%) had done three times of tillage operation for wet season in the past, whereas at present, those respondents decreased to 32.5%. Two times of tillage operation was done by 33.1% of sample respondents in the past and number of respondents increased to 66.9% at present. Only 0.6% of respondent used one time for tillage operation at present (Table 4.23).

The changes of tillage operation for wet season of sample respondents were highly significantly varied according to group of tillage operation they done ($\chi^2$ =20.12). Only 9.4% of respondents practiced two cover tillage operation in 2000 changed to three times in 2018 and the rest 90.6% continued two cover tillage operation. Forty four percent of the respondents who practiced three cover tillage operation in 2000 continued this practice, however, 55.1% percent of them changed to two cover of tillage operation in 2018 (Table 4.24).

Sixty two percent of the respondents leveled the soil before planting by using animal power in past. Although 9.4% of the sample respondents used machine for land leveling before planting in past, 74.4% practiced leveling at present. Leveling was not done by 28.1% of the sample respondents in the past and those percentages decreased to 25.6% at present (Table 4.25).

**Dry season**

Half of the respondents (56.9%) had done three times of tillage operation for dry season in the past whereas at present, those respondents decreased to 43.8%. Two covers of tillage operation were done by 29.4% of sample respondents in past and those percentages markedly increased to 55% in present. Only 0.6% of respondent practiced one cover of tillage operation in the past and increased to 1.3% in present (Table 4.26).

More than half of the respondents 61.3% leveled the field before planting by using animal power in 2000, whereas at present, those respondents decreased to 0.6%. The respondents (18.8%) who used machine for leveling before planting in past were increased to 92.5% at present. No leveling was done by 6.9% of the respondents in both past and present (Table 4.27).

**Table 4.23 Tillage operation practiced by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Tillage operation | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1 stroke | - | - | 1 | 0.6 |
| 2 stroke | 53 | 33.1 | 107 | 66.9 |
| 3 stroke | 107 | 66.9 | 52 | 32.5 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.24 Changes of tillage operation practiced by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Tillage operation (2000) | Respondents | | |
|---|---|---|---|
| | Tillage operation (2018) | | |
| | 1 stroke | 2 stroke | 3 stroke |
| 2 stroke | 0(0.0) | 48(90.6) | 5(9.4) |
| 3 stroke | 1(0.9) | 59(55.1) | 47(43.9) |
| $\chi^2$ | | 20.12*** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.25 Land leveling practiced by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Land leveling | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| By animal | 100 | 62.5 | - | - |
| By machine | 15 | 9.4 | 119 | 74.4 |
| No leveling | 45 | 28.1 | 41 | 25.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.26 Tillage operation practiced by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Tillage operation | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1 stroke | 1 | 0.6 | 2 | 1.2 |
| 2 stroke | 47 | 29.4 | 88 | 55.0 |
| 3 stroke | 91 | 56.9 | 70 | 43.8 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.27 Land leveling practiced by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Land leveling | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| By animal | 98 | 61.2 | 1 | 0.6 |
| By machines | 30 | 18.8 | 148 | 92.5 |
| No leveling | 11 | 6.9 | 11 | 6.9 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| $\chi^2$ | 105.0*** | | | |

Figures in the parentheses are percentages.
*** = significant at 1% level, n=160

#### 4.1.3.4 Rice establishment method

Almost all respondents 98.8% used transplanting method for wet season in 2000 and slightly decreased to 96.9% in 2018. Seed broadcasting method were used by few respondents 1.3% in past and at present, 3.1% used this method. Majority of the respondents 86.9% usually used seed broadcasting method for dry season in 2000 whereas almost all respondents were using seeding method in 2018. Only 0.6% of respondent used transplanting method for dry season in present (Table 4.28).

Average family labour used by respondents for establishment in wet season were 2 and 2 person $ha^{-1}$ in 2000 and 2018 respectively. Changes of family labour for establishment in wet season of the respondents during 20 years were not significantly different (t = 1.38). Respondents 68.1% did not use family labour for transplanting in 2000 and the percentage was increased to 72.5% in 2018. Regarding with family labour used in crop establishment, it was found that 18.1%, 6.3% and 4.4% of the respondents have used 1-5, 6-10 and 11-15 person $ha^{-1}$ respectively in 2000. However, the percentages of respondents in family labour usage were slightly decreased to 16.9%, 5% and 1.3%, respectively (Table 4.29).

Average hired labour used by respondents for establishment in wet season was 14 and 16 person $ha^{-1}$ in 2000 and 2018 respectively. Changes of hired labour used by respondents for establishment in wet season during 20 years were highly significantly different (t= -4.33). Respondents 8.1% did not use hired labour for transplanting in 2000 and it was decreased to 6.3% in present. Hired labour (1-10) person $ha^{-1}$ were used by respondents 11.9% in past and 6.3% of respondents used this range in 2018. Many respondents 73.1% used hired labour (11-20) persons $ha^{-1}$ in 2000 and 68.1% of them could hire these labour. The higher number of labour 21-30 and >30 were hired, respectively by few respondents (18.1% and 1.2%) in 2018 (Table 4.30).

**Dry season**

Average family labour used by respondents for establishment method in dry season was 1 and 2 person $ha^{-1}$ in past and present, respectively. Changes of family labour used by respondents for establishment in dry season during 20 years were highly significantly different (t = -2.64). Respondents 43.1% did not use family labour for seed broadcasting in the past and decreased to 35.6% in present. The number of family labour used was varied and slightly increased between 2000 and 2018. Therefore, 8.1%, 40.6% and 6.3% of respondents used 1-2, 3-4, 5-6 family labour, respectively in 2000, whereas, 10.6%, 44.4% and 7.5% of respondents used those respective numbers of family labour in order. The same percentages of respondents 1.9% used family labour (over 6) person $ha^{-1}$ in both past and present (Table 4.31).

**Table 4.28 Crop establishment method for wet and dry seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Crop establish method | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Wet season** | | | | |
| Broadcasting | 2 | 1.2 | 5 | 3.1 |
| Transplanting | 158 | 98.8 | 155 | 96.9 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Dry season** | | | | |
| Broadcasting | 139 | 86.9 | 159 | 99.4 |
| Transplanting | - | - | 1 | 0.6 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.29 Family labour used by respondents for crop establishment method in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 109 | 68.1 | 116 | 72.5 |
| 1-5 | 29 | 18.1 | 27 | 16.9 |
| 6-10 | 10 | 6.3 | 8 | 5.0 |
| 11-15 | 7 | 4.4 | 2 | 1.3 |
| 16-20 | 2 | 1.3 | 5 | 3.1 |
| 21-25 | 3 | 1.8 | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 2.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 25.0 | | 25.0 | |
| t value | $1.377^{ns}$ | | | |

n=160

**Table 4.30 Hired labour used for crop establishment of wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 13 | 8.1 | 10 | 6.3 |
| 1-10 | 19 | 11.9 | 10 | 6.3 |
| 11-20 | 117 | 73.1 | 109 | 68.1 |
| 21-30 | 11 | 6.9 | 29 | 18.1 |
| 31-40 | - | - | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 14.0 | | 16.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 30.0 | | 38.0 | |
| t value | - 4.33*** | | | |

*** = significant at 1% level, n=160

**Table 4.31 Family labour used for crop establishment method in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 69 | 43.1 | 57 | 35.6 |
| 1-2 | 13 | 8.1 | 17 | 10.6 |
| 3- 4 | 65 | 40.6 | 71 | 44.4 |
| 5- 6 | 10 | 6.3 | 12 | 7.5 |
| Over 6 | 3 | 1.9 | 3 | 1.9 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 1.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 8.0 | | 8.0 | |
| t value | -2.64*** | | | |

*** = significant at 1% level, n=160

Average hired labour for seed broadcasting used by respondents in dry season were 1 and 2 person $ha^{-1}$ in past and present respectively. Changes of hired labour used for seed broadcasting in dry season of the respondents during 20 years were highly significantly different (t = -3.29). Nearly half of the total respondents was not use hired labour for seed broadcasting in the past and decreased to 35% at present. Hired labour (1-5) person $ha^{-1}$ were used by respondents 48.1% in the past and at present 60.6% used these labour. Only 2.5% of respondents used family labour (6-10) person $ha^{-1}$ in the past and increased to 3.8% at present (Table 4.32).

Most of the respondents 95.6% transplanted rice with the seedling age of older than 28 days for wet season in the past and 89.4% of respondents used at present. The respondents 3.1% transplanted rice with young seedlings (14 days) in the past whereas at present 7.5% used the young seedlings. In past, only 1.3% of respondents was not transplanted rice and increased to 7.5% in present. For dry season, most of the respondents 86.9% were not transplanted rice and increased to 99.4% in present. Only (0.6%) of respondent who transplanted rice with young seedlings (14 days) in the present (Table 4.33).

#### 4.1.3.5 Water management

**Wet season**

Most of the respondents (93.1%) managed water for their field with permanent flooding in wet season in the past and decreased to 92.5% in present. Only seven percent of respondents used water saving technologies in the past and present. Almost all of the respondents (99.4%) obtained their water resource from rainfall in wet season and only 0.6% got their water from well or river by using water pump in both past and present (Table 4.34).

**Dry season**

Although most of the respondents (77.5%) practiced water saving technologies for summer rice in past, 91.9% of respondents used this technology at present. The respondents (9.4%) managed water for their field with permanent flooding in past and decreased to 8.1% at present. Most of the respondents (85.6%) mainly obtained their source of water from river or stream by using water pump for dry season in 2000 and the users were increased to 99.4% in present. Only 1.3% got their water resource from rainfall in past but decreased to 0.6% in present. Summer rice was not planted by 13% of the respondents in 2000 (Table 4.35).

**Table 4.32 Hired labour used for crop establishment in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 78 | 48.8 | 56 | 35.0 |
| 1-5 | 77 | 48.1 | 97 | 60.6 |
| 6-10 | 4 | 2.5 | 6 | 3.8 |
| 16-20 | 1 | 0.6 | - | - |
| 0ver 20 | - | - | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 1.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 18.0 | | 25.0 | |
| t value | - 3.29*** | | | |

*** = significant at 1% level, n=160

**Table 4.33 Use of seedling age for wet and dry seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Seedling age | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Wet season** | | | | |
| More than 14days | 5 | 3.1 | 12 | 7.5 |
| Older than 28days | 153 | 95.6 | 143 | 89.4 |
| No transplanting | 2 | 1.3 | 5 | 3.1 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Dry season** | | | | |
| No transplanting | 139 | 86.9 | 159 | 99.4 |
| More than 14days | - | - | 1 | 0.6 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.34 Water management practices in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Water management practices** | | | | |
| Permanent flooding | 149 | 93.1 | 148 | 92.5 |
| Water saving technologies | 11 | 6.9 | 12 | 7.5 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Water source** | | | | |
| Pump | 1 | 0.6 | 1 | 0.6 |
| Rainfall | 159 | 99.4 | 159 | 99.4 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.35 Water management practices in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Water management practices** | | | | |
| Permanent flooding | 15 | 9.4 | 13 | 8.1 |
| Water saving technologies | 124 | 77.5 | 147 | 91.9 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Water source** | | | | |
| Pump (river, stream) | 137 | 85.6 | 159 | 99.4 |
| Rainfall | 2 | 1.3 | 1 | 0.6 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

The changes of water management practiced by respondents for dry season were highly significantly varied according to group of water management they practiced ($\chi^2$ = 45.67). Respondents (46.7%) who managed water for their field with permanent flooding in dry season at 2000 continued this practice, however, 53.3% changed to use water saving technologies in 2018. The respondents who did not grow summer rice in 2000, but in 2018, 76.2% of them grew rice by using permanent flooding followed by 23.8% used water saving technologies. Only (0.8%) of the respondent used water saving technologies in 2000 changed to practice for their field with permanent flooding in 2018 and the rest (99.2%) continued use water saving technologies (Table 4.36).

Changes the main source of water obtained by respondents for dry season were highly significantly varied according to group of water source they obtained ($\chi^2$= 79.49). Although all respondents did not grow summer rice in 2000, they grew rice in 2018 by using water pump (Table 4.37).

#### 4.1.3.6 Fertilizer management

**Wet season**

In the past, half of the respondents 50.6% used organic fertilizers whereas only 2.5% of respondents used organic fertilizers for wet season at present. The respondents (49.4%) did not use organic fertilizers in past whereas in present those respondents increased to 97.5%. The respondents 88.8% did not apply chemical fertilizers in the past and 54.4% of them still did not use at present. Although chemical fertilizers were used by respondents (11.3%) in the past, those respondents increased to 45.6% in the present. The respondents (97.5%) did not use other fertilizers such as lime for wet season in the past and decreased to (92.5%) at present. Other fertilizers were applied by 2.5% respondents in the past whereas at present, the users increased to 7.5% (Table 4.38).

In 2000, 4.4% of respondents applied less nitrogen fertilizers for wet season compared at the present whereas respondents 2.5% used fertilizers more than in the present. Although respondents 59.4% were not applied nitrogen fertilizers but 33.8% of sample respondents used nitrogen with the same amount as in present (Table 4.39).

Average nitrogen fertilizers rate used by respondents for wet season at present was 18.9 kg $ha^{-1}$. Although many respondents 59.4% were not applied nitrogen fertilizers at present, 18.8% of sample respondents used nitrogen fertilizers at the rate of 1 to 30 kg $ha^{-1}$ for wet season. Nitrogen 31 to 60 kg $ha^{-1}$ was applied by sample respondents 13.8% and only 5.6% used 61 to 90 kg $ha^{-1}$. The rest of sample respondents applied nitrogen fertilizers (> 91kg$ha^{-1}$) (Table 4.40).

**Table 4.36 Changes of water management practices in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Water management practices (2000) | Respondents | |
|---|---|---|
| | Water management practices (2018) | |
| | Permanent flooding | Water saving technologies |
| Permanent flooding | 7(46.7) | 8(53.3) |
| No summer rice farmers | 5(23.8) | 16(76.2) |
| Water saving technologies | 1(0.8) | 123(99.2) |
| $\chi^2$ | 45.67 *** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.37 Changes the source of water supply in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Water source (2000) | Respondents | |
|---|---|---|
| | Water source (2018) | |
| | Pump | Rainfall |
| No summer rice farmers | 21(100.0) | 0(0.0) |
| Pump (river, stream) | 137(100.0) | 0(0.0) |
| Rainfall | 1(50.0) | 1(50.0) |
| $\chi^2$ | 79.49*** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.38 Soil improvement practices used for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Organic fertilizers** | | | | |
| No | 79 | 49.4 | 156 | 97.5 |
| Yes | - | - | 4 | 2.5 |
| More than present | 81 | 50.6 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Chemical fertilizers** | | | | |
| No | 142 | 88.7 | 87 | 54.4 |
| Yes | 18 | 11.3 | 73 | 45.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Other fertilizers** | | | | |
| No | 156 | 97.5 | 148 | 92.5 |
| Yes | 4 | 2.5 | 12 | 7.5 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.39 Estimation of respondents on nitrogen fertilizers used for wet season in the past (2000) in Mawlamyinegyunn Township**

| Nitrogen amount | Respondents | |
|---|---|---|
| | (2000) | |
| | Frequency | Percentage |
| Less than present | 7 | 4.4 |
| More than present | 4 | 2.5 |
| No use | 95 | 59.4 |
| Same amount as present | 54 | 33.7 |
| Total | 160 | 100.0 |

n=160

**Table 4.40 Nitrogen fertilizers used by respondents for wet season at 2018 in Mawlamyinegyunn Township**

| Nitrogen (kg ha$^{-1}$) | Respondents (2018) | |
|---|---|---|
| | Frequency | Percentage |
| No use | 95 | 59.4 |
| 1-30 | 30 | 18.8 |
| 31-60 | 22 | 13.7 |
| 61-90 | 9 | 5.6 |
| 91-120 | 3 | 1.9 |
| Over 150 | 1 | 0.6 |
| Total | 160 | 100.0 |
| Mean | 18.9 | |
| Minimum | 0.0 | |
| Maximum | 191.3 | |

n=160

Although (66.9%) respondents were not applied phosphorus fertilizers, 32.5% of sample respondents used with the same amount as in present (Table 4.41). Average rate of phosphorus fertilizers used by respondents for wet season at present was 5.6 kg $ha^{-1}$. Among the users of phosphorus fertilizers at present 10.6% of sample respondents used 1 to 10 kg $ha^{-1}$ for wet season. Phosphorus 11 to 20 kg $ha^{-1}$ was applied by 8.8% of sample respondents and 11.9% used 21 to 30 kg $ha^{-1}$. Very few respondents (1.3%) and (0.6%) applied 31 to 40 kg $ha^{-1}$ and over 50 kg $ha^{-1}$ of phosphorus fertilizers for wet season at present respectively (Table 4.42).

In the past, 0.6% of respondent applied amount of potassium fertilizers less than in the present for wet season. Although potassium was not applied by 78.2% of respondents, 21.2% of sample respondents used the same amount as in present (Table 4.43). Average rate of potassium fertilizers used by respondents for wet season in present was 5.4 kg $ha^{-1}$. Most of the respondents 78.1% were not applied potassium but 8.1% of sample respondents used with 1.1 to 15 kg $ha^{-1}$ for wet season at present. Potassium fertilizers 15.1 to 30 kg $ha^{-1}$ was applied by sample respondents (5.6%) and also 3.8% of respondents used 30.1 to 45 kg $ha^{-1}$. The sample respondents (1.3%) and (2.5%) applied 45.1 to 60 kg $ha^{-1}$ and 60.1 to 75 kg $ha^{-1}$ of potassium fertilizers respectively. And also only 0.6% of respondent used over 75 kg $ha^{-1}$ of potassium (Table 4.44).

Many respondents (88.8%) did not apply fertilizers in 2000 wet season and decreased to 54.4% at present. Among the fertilizers users in 2018, 21.9% and 15% of them were applying once and twice in crop season, respectively. Split fertilizer applications with three times were done by sample respondents 2.5% in past and increased to 7.5% in present. Only 1.3% of sample respondents used fertilizers with four times in present (Table 4.45).

There were highly significantly variation in changes of split fertilizers application done by respondents in wet season according to group of split fertilizers application they done ($\chi^2$=119.09). The respondents who changed to practice split application were largely found in one time (21.8%) and two times (14.8%) of split applications (Table 4.46).

**Table 4.41 Estimation of respondents on phosphorus fertilizers used for wet season in the past (2000) in Mawlamyinegyunn Township**

| Phosphorus amount | Respondents (2000) | |
|---|---|---|
| | Frequency | Percentage |
| Less than present | 1 | 0.6 |
| No use | 107 | 66.9 |
| Same amount as present | 52 | 32.5 |
| Total | 160 | 100.0 |

n=160

**Table 4.42 Phosphorus fertilizers used by respondents for wet season at 2018 in Mawlamyinegyunn Township**

| Phosphorus (kg $ha^{-1}$) | Respondents (2018) | |
|---|---|---|
| | Frequency | Percentage |
| No use | 107 | 66.8 |
| 1-10 | 17 | 10.6 |
| 11-20 | 14 | 8.8 |
| 21-30 | 19 | 11.9 |
| 31-40 | 2 | 1.3 |
| Over 50 | 1 | 0.6 |
| Total | 160 | 100.0 |
| Mean | 5.6 | |
| Minimum | 0.0 | |
| Maximum | 58.8 | |

n=160

**Table 4.43 Estimation of respondents on potassium fertilizers used for wet season in the past (2000) in Mawlamyinegyunn Township**

| Potassium amount | Respondents (2000) | |
|---|---|---|
| | Frequency | Percentage |
| Less than present | 1 | 0.6 |
| No use | 125 | 78.2 |
| Same amount as present | 34 | 21.2 |
| Total | 160 | 100.0 |

n=160

**Table 4.44 Potassium fertilizers used by respondents for wet season at 2018 in Mawlamyinegyunn Township**

| Potassium (kg $ha^{-1}$) | Respondents (2018) | |
|---|---|---|
| | Frequency | Percentage |
| No use | 125 | 78.1 |
| 1.1-15 | 13 | 8.1 |
| 15.1-30 | 9 | 5.6 |
| 30.1-45 | 6 | 3.8 |
| 45.1-60 | 2 | 1.3 |
| 60.1-75 | 4 | 2.5 |
| Over 75 | 1 | 0.6 |
| Total | 160 | 100.0 |
| Mean | 5.4 | |
| Minimum | 0.0 | |
| Maximum | 77.8 | |

n=160

**Table 4.45 Split fertilizer applications for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Split application | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1 time | 6 | 3.8 | 35 | 21.9 |
| 2 times | 8 | 5.0 | 24 | 15.0 |
| 3 times | 4 | 2.5 | 12 | 7.5 |
| 4 times | - | - | 2 | 1.2 |
| No application | 142 | 88.7 | 87 | 54.4 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.46 Changes of split fertilizer application for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Split application (2000) | Respondents | | | | |
|---|---|---|---|---|---|
| | Split application (2018) | | | | |
| | 1 time | 2 times | 3 times | 4 times | No application |
| 1 time | 3(50.0) | 0 (0.0) | 3(50.0) | 0 (0.0) | 0 (0.0) |
| 2 times | 1 (12.5) | 3(37.5) | 1(12.5) | 2 (25.0) | 1(12.5) |
| 3 times | 0 (0.0) | 0 (0.0) | 4(100.0) | 0 (0.0) | 0 (0.0) |
| No application | 31(21.8) | 21(14.8) | 4 (2.8) | 0 (0.0) | 86(60.6) |
| $\chi^2$ | 119.09*** | | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

Average family labour used by respondents for split fertilizer application in wet season was 0.5 and 1 person $ha^{-1}$ in past and present respectively. Changes of family labour used for split fertilizer application in wet season of the respondents during 20 years were highly significantly different (t = -6.47). Most of the respondents (89.4%) who did not use family labour for split fertilizer application in wet season at past and decreased to 63.1% in present. Only 0.6% of respondent used family labour within the range of (1-2) person $ha^{-1}$ for split fertilizer application at past and also 5.6% used these range in present. Although (8.1%) of respondents used family labour (3-4) person $ha^{-1}$ in the past, the percentages of respondents increased to 28.1% in present. Higher family labour (over 5) person $ha^{-1}$ was used by sample respondents 1.9% in past and increased to 3.1% in present (Table 4.47).

Also the changes of family labour used by respondents for split fertilizer application in wet season were highly significantly varied according to group of family labour they used ($\chi^2$=127.93). Although respondents (31.5%) who did not use family labour for fertilizer application in wet season at 2000, among them 24.5% used 3-4 person $ha^{-1}$ followed by 5.6% used 1-2 persons $ha^{-1}$ and also 1.4% used (over 5) persons $ha^{-1}$ in 2018 (Table 4.48).

Average hired labour used by respondents for split fertilizer application in wet season was 0.5 and 1 person $ha^{-1}$ in past and present respectively. Changes of hired labour for split fertilizer application in wet season used by respondents during 20 years were highly significantly different (t = -4.84). Most of the respondents 97.5% were not used hired labour in past and decreased to 81.3% in present. The percentages of respondents used hired labour (3-4) person $ha^{-1}$ increased from 1.9% in past to 12.5% in present. Only 3.8% and 1.9% of respondents used hired labour (1-2) person $ha^{-1}$ and (5-6) persons $ha^{-1}$ in present. Highest hired labour (7-8) person $ha^{-1}$ were used by sample respondents only 0.6% in both past and present (Table 4.49).

Changes of hired labour used by respondents for split fertilizer application in wet season were highly significantly varied according to group of hired labour they used ($\chi^2$=28.71). Although 16.6% of respondents were not used hired labour for fertilizer application in wet season at 2000, among them 10.3% used 3-4 person $ha^{-1}$ followed by 3.8% used 1-2 person $ha^{-1}$, 1.9% used to 5-6 person $ha^{-1}$ and 0.6% used 7-8 person $ha^{-1}$ in 2018, respectively (Table 4.50).

**Table 4.47 Family labour used for split application in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 143 | 89.4 | 101 | 63.1 |
| 1-2 | 1 | 0.6 | 9 | 5.6 |
| 3-4 | 13 | 8.1 | 45 | 28.2 |
| Over 5 | 3 | 1.9 | 5 | 3.1 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 0.5 | | 1.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 5.0 | | 5.0 | |
| t value | -6.47*** | | | |

***= significant at 1% level, n=160

**Table 4.48 Changes of family labour used for split application in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) (2000) | Respondents | | | |
|---|---|---|---|---|
| | Family labour (person ha$^{-1}$) (2018) | | | |
| | No use | 1-2 | 3-4 | Over 5 |
| No use | 98(68.5) | 8(5.6) | 35(24.5) | 2(1.4) |
| 1-2 | 0(0.0) | 1(100.0) | 0(0.0) | 0(0.0) |
| 3-4 | 3(23.1) | 0(0.0) | 10(76.9) | 0(0.0) |
| Over 5 | 0(0.0) | 0(0.0) | 0(0.0) | 3(100.0) |
| $\chi^2$ | 127.93*** | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.49 Hired labour used for split application in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 156 | 97.5 | 130 | 81.3 |
| 1- 2 | - | - | 6 | 3.8 |
| 3- 4 | 3 | 1.9 | 20 | 12.4 |
| 5- 6 | - | - | 3 | 1.9 |
| 7- 8 | 1 | 0.6 | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 0.5 | | 1.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 8.0 | | 8.0 | |
| t value | -4.84*** | | | |

***= significant at 1% level, n=160

**Table 4.50 Changes of hired labour used for split fertilizer application in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) (2000) | Respondents | | | | |
|---|---|---|---|---|---|
| | Hired labour (person ha$^{-1}$) (2018) | | | | |
| | No use | 1-2 | 3- 4 | 5- 6 | 7- 8 |
| No use | 130(83.3) | 6(3.8) | 16(10.3) | 3(1.9) | 1(0.6) |
| 3- 4 | 0 (0.0) | 0 (0.0) | 3 (100.0) | 0 (0.0) | 0 (0.0) |
| 7- 8 | 0 (0.0) | 0 (0.0) | 1(100.0) | 0 (0.0) | 0 (0.0) |
| $\chi^2$ | 28.72*** | | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Dry season**

In the past, 32.5% of respondents used organic fertilizers with more than present in the dry season. The percentages of respondents 54.4% were not used organic fertilizers in past whereas in present those users were increased to 98.8%. Only 1.3% of respondents used organic fertilizers at present. Although 75% of respondents applied chemical fertilizers for dry season in the past, at present, all respondents used chemical fertilizers for dry season. In the past, most of the respondents (86.9%) did not use other fertilizers for dry season and increased to 98.8% in present. Only 1.3% of sample respondents applied other fertilizers in present (Table 4.51).

In past, 37.5% of sample respondents applied nitrogen which was less than in the present and 30.6% used same amount of fertilizers compared to the present. Although 12.5% of sample respondents did not apply nitrogen fertilizers at all in 2000, the rest of the respondents applied nitrogen fertilizers with different rates (Table 4.52). Average nitrogen fertilizers rate used by respondents for dry season in present was 113.3 kg $ha^{-1}$. One third of the total respondents used 80.1 to 120 kg $ha^{-1}$ of nitrogen fertilizers and 23.8% of the respondents used 160.1 to 200 kg $ha^{-1}$ of nitrogen fertilizers. The percentages of the respondents 21.3% and 15.6% applied 40.1 to 80 kg $ha^{-1}$ and 120.1 to 160 kg $ha^{-1}$ of nitrogen, respectively. The lowest amount of nitrogen 1.1 to 40 kg $ha^{-1}$ was applied by only 6.3% of sample respondents for dry season in present (Table 4.53).

Although phosphorus fertilizer was not applied by 38.8% of sample respondents in 2000, 40% of respondents estimated that they used same amount as at present (Table 4.54). In 2000, average rate of phosphorus fertilizers used by respondents for dry season was 24.8 kg $ha^{-1}$. Most of the respondents (68.8%) applied 15.1 to 30 kg $ha^{-1}$ but only 3.8% did not apply in present. Respondents (13.8%) used 1 to 15 kg $ha^{-1}$ followed by 6.9% (30.1 to 45 kg $ha^{-1}$) and 5% (45.1 to 60 kg $ha^{-1}$), respectively. Only 1.3% and 0.6% of respondents applied phosphorus fertilizers with the highest amount of 60.1 to 75 kg $ha^{-1}$ and over 75 kg $ha^{-1}$, respectively for dry season in present (Table 4.55).

Most of the respondents (74.4%) did not apply potassium fertilizers for dry season in 2000 and only 1.3% used potassium fertilizers less than the rate of present. Potassium fertilizers were applied by 11.3% sample respondents with the same amount as used in present (Table 4.56). Average rate of potassium fertilizers used by respondents for dry season at present was 18.9 kg $ha^{-1}$. Half of the total respondents did not apply potassium but 15.6%, 18.1% and 14.4% used 1 to 25 kg $ha^{-1}$, 25.1 to 50 kg $ha^{-1}$ and 50.1 to 75 kg $ha^{-1}$, respectively. The high rates of 75.1 to 100 kg $ha^{-1}$ and >125 kg $ha^{-1}$ of potassium fertilizers were applied by 1.3% and 0.6% of respondents at present (Table 4.57).

**Table 4.51 Soil improvement practices used in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Items | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Organic fertilizers** | | | | |
| Yes | - | - | 2 | 1.2 |
| More than present | 52 | 32.5 | - | - |
| No | 87 | 54.4 | 158 | 98.8 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Chemical fertilizers** | | | | |
| No | 19 | 11.9 | - | - |
| Yes | 120 | 75.0 | 160 | 100 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100 |
| **Other fertilizers** | | | | |
| No | 139 | 86.9 | 158 | 98.8 |
| Yes | - | - | 2 | 1.2 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.52 Estimation of respondents on nitrogen fertilizers used for dry season in the past (2000) in Mawlamyinegyunn Township**

| Nitrogen amount | Respondents | |
|---|---|---|
| | (2000) | |
| | Frequency | Percentage |
| Less than present | 60 | 37.5 |
| More than present | 10 | 6.3 |
| No use | 20 | 12.5 |
| Same amount as present | 49 | 30.6 |
| No summer rice farmers | 21 | 13.1 |
| Total | 160 | 100.0 |

n=160

**Table 4.53 Nitrogen fertilizers used by respondents for dry season at 2018 in Mawlamyinegyunn Township**

| Nitrogen (kg ha$^{-1}$) | Respondents (2018) | |
|---|---|---|
| | Frequency | Percentage |
| 1.1-40 | 10 | 6.3 |
| 40.1-80 | 34 | 21.3 |
| 80.1-120 | 53 | 33.1 |
| 120.1-160 | 25 | 15.6 |
| 160.1-200 | 38 | 23.7 |
| Total | 160 | 100.0 |
| Mean | 113.3 | |
| Minimum | 4.3 | |
| Maximum | 197.5 | |

n=160

**Table 4.54 Estimation of respondents on phosphorus fertilizers used for dry season in the past (2000) in Mawlamyinegyunn Township**

| Phosphorus amount | Respondents (2000) | |
|---|---|---|
| | Frequency | Percentage |
| Less than present | 12 | 7.5 |
| More than present | 1 | 0.6 |
| No use | 62 | 38.8 |
| Same amount as present | 64 | 40.0 |
| No summer rice farmers | 21 | 13.1 |
| Total | 160 | 100.0 |

n=160

**Table 4.55 Phosphorus fertilizers used by respondents for dry season at 2018 in Mawlamyinegyunn Township**

| Phosphorus (kg ha$^{-1}$) | Respondents (2018) | |
|---|---|---|
| | Frequency | Percentage |
| No use | 6 | 3.8 |
| 1-15 | 22 | 13.7 |
| 15.1-30 | 110 | 68.7 |
| 30.1-45 | 11 | 6.9 |
| 45.1-60 | 8 | 5.0 |
| 60.1-75 | 2 | 1.3 |
| Over75 | 1 | 0.6 |
| Total | 160 | 100.0 |
| Mean | 24.8 | |
| Minimum | 4.0 | |
| Maximum | 75.9 | |

n=160

**Table 4.56 Estimation of respondents on potassium fertilizers used for dry season in the past (2000) in Mawlamyinegyunn Township**

| Potassium amount | Respondents (2000) | |
|---|---|---|
| | Frequency | Percentage |
| Less than present | 2 | 1.3 |
| No use | 119 | 74.3 |
| Same amount as present | 18 | 11.3 |
| No summer rice farmers | 21 | 13.1 |
| Total | 160 | 100.0 |

n=160

**Table 4.57 Potassium fertilizers used by respondents for dry season at 2018 in Mawlamyinegyunn Township**

| Potassium (kg ha$^{-1}$) | Respondents (2018) | |
|---|---|---|
| | **Frequency** | **Percentage** |
| No use | 80 | 50.0 |
| 1-25 | 25 | 15.6 |
| 25.1-50 | 29 | 18.1 |
| 50.1-75 | 23 | 14.4 |
| 75.1-100 | 2 | 1.3 |
| Over125 | 1 | 0.6 |
| Total | 160 | 100.0 |
| Mean | 18.9 | |
| Minimum | 5.2 | |
| Maximum | 77.8 | |

n=160

Five percent of respondents applied fertilizers about one time for dry season in past and decreased to 0.6% in present. Two times of split fertilizer applications were done by (15.6%) of sample respondents in both past and present. The percentages of respondents used three times of split application increased from 53.1% in past to 75.6% in present. Only 1.3% of sample respondents applied fertilizer four times in past and increased to 8.1% in present (Table 4.58).

Changes of split fertilizers application done by respondents for dry season were highly significantly varied according to group of split fertilizers application they used ($\chi^2$=84.09). Among respondents applied one time of split fertilizers in 2000, 25% changed to use two times and 62.5% used three times in 2018. Among them, two times, three times and four times were respectively done by 21.1%, 68.4% and 10.5%. Dry season rice was not grown by sample respondents (100%) in 2000 but in 2018, they grew dry season rice. Among them, 23.8% applied split fertilizers with two times and 66.7% used three times and 9.5% used four times for dry season (Table 4.59).

Average family labour used by respondents for split fertilizer application in dry season was 1 and 2 person $ha^{-1}$ in past and present respectively. Changes of family labour used for split fertilizer application in dry season of the respondents during 20 years were highly significantly different (t = -3.69). The respondents 45% were not used family labour for split fertilizer application in past and decreased to 30.6% in present. Ten percent of the respondents used family labour within the range of (1-2) person $ha^{-1}$ past and in present 15.6% used these range of family labour. The percentages of respondents used family labour (3-4) person $ha^{-1}$ increased from 42.5% in past to 49.4% in present. Higher family labour (over 5) person $ha^{-1}$ used by sample respondents 2.5% in past and increased to 4.4% in present (Table 4.60).

Average hired labour used by respondents for split fertilizer application in dry season was 1 and 2 person $ha^{-1}$ in past and present respectively. Changes of hired labour used for split fertilizer application in dry season of the respondents during 20 years were highly significantly different (t = -7.55). Most of the respondents (64.4%) who did not use hired labour for split fertilizer application in past and decreased to 35% in present. Although respondents 32.5% used hired labour between the ranges of (1-2) person $ha^{-1}$ in past, 59.4% of respondents used these range in present. Hired labour (3-4) person $ha^{-1}$ used by sample respondents percentages increased from 3.1% in past to 5% in present. Only 0.6% of sample respondent used hired labour (over 5) person $ha^{-1}$ in present (Table 4.61).

**Table 4.58 Split fertilizer applications for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Split fertilizer application | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1 time | 8 | 5.0 | 1 | 0.6 |
| 2 times | 25 | 15.6 | 25 | 15.6 |
| 3 times | 85 | 53.1 | 121 | 75.6 |
| 4 times | 2 | 1.3 | 13 | 8.2 |
| No application | 19 | 11.9 | - | - |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.59 Changes of split fertilizer application for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Split fertilizer application (2000) | Respondents | | | |
|---|---|---|---|---|
| | Split fertilizer application (2018) | | | |
| | 1 time | 2 times | 3 times | 4 times |
| 1 time | 1(12.5) | 2(25.0) | 5(62.5) | 0(0.0) |
| 2 times | 0(0.0) | 13(52.0) | 11(44.0) | 1(4.0) |
| 3 times | 0(0.0) | 1(1.2) | 78(91.8) | 6(7.1) |
| 4 times | 0(0.0) | 0(0.0) | 0(0.0) | 2(100.0) |
| No application | 0(0.0) | 4(21.1) | 13(68.4) | 2(10.5) |
| No summer rice farmers | 0(0.0) | 5(23.8) | 14(66.7) | 2(9.5) |
| $\chi^2$ | 84.09*** | | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.60 Family labour used for split application of dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 72 | 45.0 | 49 | 30.6 |
| 1-2 | 16 | 10.0 | 25 | 15.6 |
| 3-4 | 68 | 42.5 | 79 | 49.4 |
| Over 5 | 4 | 2.5 | 7 | 4.4 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 1.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 5.0 | | 5.0 | |
| t value | -3.7*** | | | |

***= significant at 1% level, n=160

**Table 4.61 Hired labour used for split fertilizer application in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 103 | 64.4 | 56 | 35.0 |
| 1-2 | 52 | 32.5 | 95 | 59.4 |
| 3-4 | 5 | 3.1 | 8 | 5.0 |
| Over 5 | - | - | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 1.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 5.0 | | 8.0 | |
| t value | -7.55*** | | | |

***= significant at 1% level, n=160

#### 4.1.3.7 Weed management

**Wet season**

Weed control was not practiced by (94.4%) of respondents in wet season in past and those percentages were decreased to 90% in present. Hand weeding was practiced by (5.6%) of sample respondents in past and in present, only 3.8% practiced manual weed control. Only 6.3% of respondents changed to use chemical herbicide for weed control at present (Table 4.62).

Average family labour used by respondents for weed control in wet season was 0.5 and 0.5 person $ha^{-1}$ in past and present respectively. Changes of family labour used for weed management in wet season of the respondents during 20 years were not significantly different (t = 0.30). In past, most of the respondents (94.4%) did not use family labour for weed control and increased to 96.3% in present. Only 2.5% of respondents used family labour within the range of (1-2) person $ha^{-1}$ in past and also 1.3% used these range in present. Higher family labour between the ranges of (3-4) person $ha^{-1}$ was used by sample respondents 3.1% in past and decreased to 1.3% in present. Only 1.3% respondents who used higher family labour (over 5) person $ha^{-1}$ in present (Table 4.63).

Average hired labour used by respondents for weed control in wet season was 0.5 and 0.5 person $ha^{-1}$ in past and present respectively. Changes of hired labour used by respondents for weed control in wet season during 20 years were not significantly different (t = -0.28). Most of the respondents (98.1%) who did not use hired labour for weed control in past and increased to 98.8% in present. In present, the same percentages of respondents 0.6% used family labour (1-5) person $ha^{-1}$ and (11-15) person $ha^{-1}$ (Table 4.64).

**Dry season**

Weed control was not practiced by respondents (58.8%) for dry season in past and decreased to 15% in present. The respondents who practiced manual weed control decreased from 4.4% in past to 1.3% at present. The respondents who used chemical herbicide for weed control markedly increased from 23.8% in the past to 83.8% at present (Table 4.65).

**Table 4.62 Weed control methods practiced by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Weed control methods | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Manual | 9 | 5.6 | 6 | 3.8 |
| Chemical | - | - | 10 | 6.2 |
| No weed control | 151 | 94.4 | 144 | 90.0 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.63 Family labour used by respondents for weed control in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 151 | 94.4 | 154 | 96.4 |
| 1-2 | 4 | 2.5 | 2 | 1.2 |
| 3-4 | 5 | 3.1 | 2 | 1.2 |
| 0ver 5 | - | - | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 0.5 | | 0.5 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 5.0 | | 8.0 | |
| t value | $0.30^{ns}$ | | | |

ns = non significant, n=160

**Table 4.64 Hired labour used by respondents for weed control in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 157 | 98.1 | 158 | 98.8 |
| 1-5 | 3 | 1.9 | 1 | 0.6 |
| 11-15 | - | - | 1 | 0.6 |
| Total | 160 | 100 | 160 | 100 |
| Mean | 0.5 | | 0.5 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 5.0 | | 15.0 | |
| t value | - 0.28$^{ns}$ | | | |

ns = non significant, n=160

**Table 4.65 Weed control methods practiced by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Weed control methods | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Chemical | 38 | 23.8 | 134 | 83.8 |
| Manual | 7 | 4.4 | 2 | 1.2 |
| No weed control | 94 | 58.7 | 24 | 15.0 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

Changes of weed control practiced by respondents for dry season were highly significantly varied according to group of weed management they practiced ($\chi^2$=25.1). Respondents who practiced manual weed control for dry season in 2000 changed to use chemical herbicide in 2018. Respondents (79.8%) who did not practice for weed control in 2000 changed practice for weed control by using chemical herbicide in 2018 and the rest (20.2%) continued no weed control. Among the respondents who did not grow rice in 2000, herbicide was used by 66.7% followed by 9.5% (hand weeding) and 23.8% (no weed control), respectively (Table 4.66).

In 2000, (58.8%) of respondents did not practice weed control for dry season and decreased to 15% in present. Respondents (22.5%) who did weed control about one time in past and markedly increased to 70% in present. The percentages of respondents who practiced for weed control about two times increased from 3.8% in past to 13.1% in present. Between past and present, the same percentages of respondents (1.9%) were done weed control with three times (Table 4.67).

#### 4.1.3.8 Pest and disease management

Twenty eight percent of the respondents practiced pest and disease control by using chemical in past and increased to 78.8% at present. The percentages of respondents did not practice pest and disease control decreased from 71.9% in past to 23.1% in present. Most of the respondents (90.6%) did not control birds infestation in past and they decreased to 89.4% in present. The percentages of respondents who practiced birds controls increased from 9.4% in past to 10.6% in present (Table 4.68).

#### 4.1.3.9 Methods of harvesting and threshing

Overall respondents harvested rice by manually for wet season in 2000. This practice was not changed evidently in 2018. Most of the respondents (85.6%) harvested rice by manually for dry season in past whereas in present these respondents substantially decreased to 11.3%. Only 1.3% of respondents used combine harvester in past and those respondents markedly increased to 88.8% at 2018 (Table 4.69).

The changes of harvesting methods used by respondents for dry season were significantly varied according to group of harvesting method they used ($\chi^2$= 3.06). Respondents (86.9%) who harvested rice by manually for dry season in 2000 changed to use combine harvester in 2018. All sample respondents who did not grow rice in 2000 and used combine harvester in 2018 (Table 4.70).

**Table 4.66 Changes of weed control methods practiced for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Weed control methods (2000) | Respondents | | |
|---|---|---|---|
| | Weed control methods (2018) | | |
| | Chemical | Manual | No weed control |
| Chemical | 38(100.0) | 0(0.0) | 0(0.0) |
| Manual | 7(100.0) | 0(0.0) | 0(0.0) |
| No weed control | 75(79.8) | 0(0.0) | 19(20.2) |
| No summer rice farmers | 14(66.7) | 2(9.5) | 5(23.8) |
| $\chi^2$ | | 25.1*** | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

**Table 4.67 Weed management frequency practiced for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Weed management frequency | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1 time | 36 | 22.5 | 112 | 70.0 |
| 2 times | 6 | 3.8 | 21 | 13.1 |
| 3 times | 3 | 1.8 | 3 | 1.9 |
| No | 94 | 58.8 | 24 | 15 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.68 Pest and disease control practiced by respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Control practices | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Pest and disease management** | | | | |
| Chemical | 45 | 28.1 | 126 | 78.7 |
| No pest and disease control | 115 | 71.9 | 34 | 21.3 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Birds control** | | | | |
| No | 145 | 90.6 | 143 | 89.4 |
| Yes | 15 | 9.4 | 17 | 10.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.69 Harvesting methods used by respondents for wet and dry seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Harvesting methods | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Wet season** | | | | |
| Manual | 160 | 100 | 158 | 98.8 |
| Combine harvester | - | - | 2 | 1.2 |
| Total | 160 | 100 | 160 | 100.0 |
| **Dry season** | | | | |
| Manual | 137 | 85.6 | 18 | 11.2 |
| Combine harvester | 2 | 1.3 | 142 | 88.8 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.70 Changes of harvesting methods used by respondents for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Harvesting methods (2000) | Respondents | |
|---|---|---|
| | Harvesting methods (2018) | |
| | Combine harvester | Manual |
| Combine harvester | 2(100.0) | 0(0.0) |
| Manual | 119(86.9) | 18(13.1) |
| No summer rice farmers | 21(100.0) | 0(0.0) |
| $\chi^2$ | 3.4** | |

Figures in the parentheses are percentages.

** = significant at 5% level, n=160

Average family labour used for manual harvesting in wet season was 2 and 1 person $ha^{-1}$ in past and present respectively. Changes of family labour used by respondents for manual harvesting in wet season during 20 years were significantly different (t = 2.05). Many respondents (71.3%) did not use family labour for manual harvesting in wet season in the past and increased to 76.9% in present. Twenty percent of respondents used family labour within the range of (1-5) person $ha^{-1}$ in the past but 16.3% of respondents used this range of labours at present. More than 5 family labours in harvesting were used by very few respondents in both past and present (Table 4.71).

Average hired labours used by respondents for manual harvesting in wet season were 15 and 17 person $ha^{-1}$ in past and present respectively. Changes of hired labour used by respondents for manual harvesting in wet season during 20 years were highly significantly different (t = -3.3). The respondents who did not use hired labour in past and present were about 3% only. The percentages of respondents who used hired labour between the range of (1-10) person $ha^{-1}$ decreased from 13.8% in past to 8.8% at present. Between past and present, the same percentages of respondents (71.9%) used hired labour (11-20) person $ha^{-1}$ for manual harvesting (Table 4.72).

**Dry season**

Average family labour used by respondents for harvesting in dry season were 2 and 0.5 person $ha^{-1}$ in past and present respectively. Changes of family labour used by respondents for manual harvesting during 20 years were highly significantly different (t = 4.65). Most respondents (80.6%) did not use family labour for manual harvesting in dry season in the past and increased to 96.9% at present. Although (10.6%) of respondents used family labour within the range of (1-5) person $ha^{-1}$ in past, only 2.5% used this range in present. In past, 2.5% and 1.9% of respondents respectively used family labour (6-10) person $ha^{-1}$ and (11-15) person $ha^{-1}$ but they did not use family labours at present (Table 4.73).

Changes of family labour used by respondents for harvesting in dry season were highly significantly varied according to group of family labour they used ($\chi^2$=56.46). It was found that 129 respondents who did not use family labours were not changed their practices. Among the respondents who respectively used 1-5, 6-10, 11-15 and 16-20 family labours, 76.5%, 100%, and 85.7% of them were changed their practices to no family labour usage in 2018. That is why no family labours users were increased from 129 to 155 during 20 years (Table 4.74).

**Table 4.71 Family labour used for manual harvesting in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 114 | 71.3 | 123 | 76.9 |
| 1-5 | 32 | 20.0 | 26 | 16.3 |
| 6-10 | 7 | 4.4 | 7 | 4.4 |
| 11-15 | 5 | 3.1 | 1 | 0.6 |
| >15 | 2 | 1.2 | 3 | 1.8 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 2.0 | | 1.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 25.0 | | 25.0 | |
| t value | 2.05** | | | |

** = significant at 5% level, n=160

**Table 4.72 Hired labour used for manual harvesting in wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 6 | 3.8 | 5 | 3.1 |
| 1-10 | 22 | 13.8 | 14 | 8.8 |
| 11-20 | 115 | 71.9 | 115 | 71.9 |
| 21-30 | 17 | 10.5 | 24 | 15.0 |
| 31-40 | - | - | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 15.0 | | 17.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 30.0 | | 38.0 | |
| t value | -3.3*** | | | |

***= significant at 1% level, n=160

**Table 4.73 Family labour used for harvesting in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 129 | 80.6 | 155 | 96.9 |
| 1-5 | 17 | 10.6 | 4 | 2.5 |
| 6-10 | 4 | 2.5 | - | - |
| 11-15 | 3 | 1.9 | - | - |
| 16-20 | 7 | 4.4 | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 2.0 | | 0.5 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 25.0 | | 20.0 | |
| t value | 4.65*** | | | |

***= significant at 1% level, n=160

**Table 4.74 Changes of family labour used for harvesting in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Family labour (person ha$^{-1}$) (2000) | Respondents | | |
|---|---|---|---|
| | Family labour (2018) | | |
| | No use | 1-5 | 16-20 |
| No use | 129(100.0) | 0(0.0) | 0(0.0) |
| 1-5 | 13(76.5) | 4(23.5) | 0(0.0) |
| 6-10 | 4(100.0) | 0(0.0) | 0(0.0) |
| 11-15 | 3(100.0) | 0 (0.0) | 0 (0.0) |
| 16-20 | 6(85.7) | 0(0.0) | 1(14.3) |
| $\chi^2$ | 56.46*** | | |

Figures in the parentheses are percentages.

*** = significant at 1% level, n=160

Average hired labours used by respondents for harvesting in dry season were apparently decreased from 16 to 2 person $ha^{-1}$ during 20 years. Changes of hired labour used by respondents for manual harvesting in dry season during 20 years were highly significantly different (t = 17.92). The respondents 19.4% who did not use hired labour for manual harvesting in past increased to 89.4% in present. Hired labour within the range of (11-20) person $ha^{-1}$ used by 56.9% of respondents in past but only 10% used this range in present. Respondents 18.8% used hired labour (21-30) person $ha^{-1}$ in past and substantially decreased to 0.6% in present. Only 1.9% of sample respondents used hired labour between the range of (31-40) person $ha^{-1}$ in past (Table 4.75).

Changes of hired labour used by respondents for harvesting in dry season were significantly varied according to group of hired labour they used ($\chi^2$= 16.95). Hired labour between the range of (1-10) and (31-40) person $ha^{-1}$ used by respondents in 2000 did not use hired labours in 2018. In 2000, 82.8% and 96.7% of respondents who respectively used (11-20) and (21-30) hired labours changed no use of labours in 2018. These changes showed the increased number of respondents who did not use hired labours due to machine usage in harvesting (Table 4.76).

In the past, 49.4% of respondents threshed rice by using animal for wet season. The respondents (2.5%) threshed rice by manually in past and decreased to 1.3% in present. Mechanical thresher used by sample respondents increased from 48.1% in past to 98.1% in present. Only 0.6% of sample respondent used combined harvester for threshing of rice at present (Table 4.77).

#### 4.1.3.10 Grain yield

**Wet season**

Average rice yield for wet season obtained by respondents were as much as the same about 2.9 ton $ha^{-1}$ in past and present respectively. Changes of rice yield for wet season obtained by respondents during 20 years were highly significantly different (t= -2.92). The respondents 14.4% got 1-2 ton $ha^{-1}$ of rice yield in past whereas in present only 7.5% of respondents obtained this yield in wet season. Most of the respondents (84.4%) obtained 2.1 to 4 ton $ha^{-1}$ of rice yield in past and this increase yield was obtained by 90.6% in present (Table 4.78).

The changes of rice yield obtained by respondents for wet season were highly significantly varied according to group of rice yield they obtained ($\chi^2$=45.87). Thirty percent of respondents who obtained 1-2 ton $ha^{-1}$ of rice yield in 2000 were still obtained this yield, however, 69.6% of this group increased their rice yield up to 2.1-4 ton $ha^{-1}$ in 2018. Respondents who obtained 2.1-4 ton $ha^{-1}$ of rice yield in 2000 could not change their rice yield, thus 94.8% of respondents in this group obtained this yield (Table 4.79).

**Table 4.75 Use of hired labour for harvesting in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No use | 31 | 19.4 | 143 | 89.4 |
| 1-10 | 5 | 3.1 | - | - |
| 11-20 | 91 | 56.9 | 16 | 10.0 |
| 21-30 | 30 | 18.8 | 1 | 0.6 |
| 31-40 | 3 | 1.8 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 16.0 | | 2.0 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 38.0 | | 25.0 | |
| t value | 17.92*** | | | |

***= significant at 1% level, n=160

**Table 4.76 Changes of hired labour used by respondents for harvesting in dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Hired labour (person ha$^{-1}$) (2000) | Respondents | | |
|---|---|---|---|
| | Hired labour (2018) | | |
| | No use | 11-20 | 21-30 |
| No use | 29(100.0) | 0(0.0) | 0(0.0) |
| 1-10 | 5(100.0) | 0(0.0) | 0(0.0) |
| 11-20 | 77(82.8) | 16(17.2) | 0(0.0) |
| 21-30 | 29(96.7) | 0(0.0) | 1(3.3) |
| 31-40 | 3(100.0) | 0(0.0) | 0(0.0) |
| $\chi^2$ | 16.95** | | |

Figures in the parentheses are percentages.

** = significant at 5% level, n=160

**Table 4.77 Threshing method used by respondents for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Threshing method | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Animal | 79 | 49.4 | - | - |
| Manual | 4 | 2.5 | 2 | 1.3 |
| Mechanical | 77 | 48.1 | 157 | 98.1 |
| Combined | - | - | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.78 Rice yield per hectare for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice yield (ton ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 1-2 | 23 | 14.4 | 12 | 7.5 |
| 2.1-4 | 135 | 84.4 | 145 | 90.6 |
| 4.1-6 | 2 | 1.2 | 3 | 1.9 |
| Total | 160 | 100 | 160 | 100 |
| Mean | 2.8 | | 2.9 | |
| Minimum | 1.3 | | 1.8 | |
| Maximum | 5.0 | | 5.0 | |
| t value | -2.92*** | | | |

*** = significant at 1% level, n=160

**Table 4.79 Changes of rice yield per hectare for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice yield (ton ha$^{-1}$) (2000) | Respondents | | |
|---|---|---|---|
| | Rice yield (2018) | | |
| | 1-2 | 2.1- 4 | 4.1-6 |
| 1-2 | 7(30.4) | 16(69.6) | 0(0.0) |
| 2.1-4 | 5(3.7) | 128(94.8) | 2(1.5) |
| 4.1-6 | 0(0.0) | 1(50.0) | 1(50.0) |
| $\chi^2$ | 45.87*** | | |

Figures in the parentheses are percentages.
*** = significant at 1% level, n=160

**Dry season**

Average rice yield obtained by respondents for dry season were 3.9 and 5 ton $ha^{-1}$ in past and present respectively. Changes of rice yield during 20 years were highly significantly different (t = -7.95). The respondents (34.4%) got 2.1 to 4 ton $ha^{-1}$ of rice yield in past whereas in present only 9.4% of respondents obtained this yield. Although half of the total respondents obtained 4.1 to 6 ton $ha^{-1}$ of rice yield in past, 88.7% of respondents got this yield in present. Over 6 ton $ha^{-1}$ of rice yield were obtained by only 0.6 % of the respondents in the past and increased to 1.9% in present (Table 4.80).

However, the changes of rice yield obtained by respondents for dry season were not significantly varied according to group of rice yield they obtained ($\chi^2$=10.28). Although sample respondents who could not grow rice in 2000, they cultivated dry season rice in 2018, and 85.7% of them got 4 to 6 ton $ha^{-1}$. Eighteen percent of respondents obtained 2 to 4 ton $ha^{-1}$ in 2000, however, 81.8% of them increased their rice yield up to 4 to 6 ton $ha^{-1}$ in 2018. The respondents who got 4 to 6 ton $ha^{-1}$ of rice in 2000, 94% of them continuously got this yield in 2018. Therefore, majority of respondents obtained higher yield 4-6 ton $ha^{-1}$ in 2018 compared with 2000 (Table 4.81).

### 4.1.4 Postharvest management practices for both seasons

Most of the respondents (90.6%) usually dried rice before selling in past and increased to 94.4% in present. The percentages of respondents was not dried for rice decreased from 9.4% in past to 5.6% in present (Table 4.82). Incorporating straw into the soil for manuring was increasingly done by 22.5% to 36.3% of the respondents during 20 years. The respondents (47.5%) removed straw for animal feeding in past and decreased to 16.9% in present. The percentages of respondents who burned rice straw increased from 29.4% in past to 46.3% in present (Table 4.83).

Respondents (51.9%) usually used hired labour for post-harvest activities (such as drying, storage etc.) in past and increased to 56.9% in present. Post-harvest activities were not practiced by 7.5% sample respondents in past and those percentages decreased to 3.8% in present. Respondents (40.6%) who did not use hired labour for post-harvest activities in past and decreased to 39.4% in present (Table 4.84).

For wet season, most of the respondents about (85%) kept their rice for home consumption in past and present. Storing their rice for home consumption was not done by 15% and 13.8 % at present. In past, respondents (68.8%) did not keep their rice for home consumption for dry season and the percentages was increased to 77.5% in present. Respondents 18.1% who stored their rice for home consumption in dry season and these percentages of sample respondents increased to 22.5% in present (Table 4.85).

**Table 4.80 Rice yield per hectare for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice yield (ton ha$^{-1}$) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| 2.1-4 | 55 | 34.4 | 15 | 9.4 |
| 4.1-6 | 83 | 51.9 | 142 | 88.7 |
| Over 6 | 1 | 0.6 | 3 | 1.9 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 3.9 | | 5.0 | |
| Minimum | 0.0 | | 3.0 | |
| Maximum | 7.0 | | 7.0 | |
| t value | -7.95*** | | | |

*** = significant at 1% level, n=160

**Table 4.81 Changes of rice yield per hectare for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice yield (ton ha$^{-1}$) (2000) | Respondents | | |
|---|---|---|---|
| | Rice yield (2018) | | |
| | 2-4 | 4-6 | Over 6 |
| No summer rice farmers | 2(9.5) | 18(85.7) | 1(4.8) |
| 2-4 | 10(18.2) | 45(81.8) | 0(0.0) |
| 4-6 | 3(3.6) | 78(94.0) | 2(2.4) |
| Over 6 | 0(0.0) | 1(100.0) | 0(0.0) |
| $\chi^2$ | $10.28^{ns}$ | | |

Figures in the parentheses are percentages.
ns = non significant, n=160

**Table 4.82 Drying of rice practiced by respondents for both seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Drying of rice | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Drying (Sun) | 145 | 90.6 | 151 | 94.4 |
| Non drying | 15 | 9.4 | 9 | 5.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.83 Rice straw management for both seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Rice straw management | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Returned | 36 | 22.5 | 58 | 36.3 |
| Removed | 76 | 47.5 | 27 | 16.8 |
| Burned | 47 | 29.4 | 74 | 46.3 |
| Erratic | 1 | 0.6 | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.84 Post-harvest activities practiced by respondents for both seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Post - harvest activities | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Hired | 83 | 51.9 | 91 | 56.9 |
| No post-harvest activities | 12 | 7.5 | 6 | 3.7 |
| Non hired | 65 | 40.6 | 63 | 39.4 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.85 Storage of rice for home consumption in both seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Storage of rice | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| **Wet season** | | | | |
| No | 24 | 15.0 | 22 | 13.7 |
| Yes | 136 | 85.0 | 138 | 86.3 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Dry season** | | | | |
| No | 110 | 68.8 | 124 | 77.5 |
| Yes | 29 | 18.1 | 36 | 22.5 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

### 4.1.5 Market condition for rice selling in both seasons

Most of the respondents about (78%) sold their rice to milling company in past and present. During 20 years, the same percentages of respondents 15% sold their rice to local collector. Rice was sold by the same percentages of respondents (3.1%) to rice brokers in both past and present. At past and present, same percentages of respondents 3.1% sold their rice to others. Only 1.3% of respondents did not sell in past and those respondents decreased to 0.6% in present (Table 4.86).

Regarding with average amount of rice sold by respondents for wet season were 7.8 and 9.1 tons in past and present respectively. Changes amount of rice sold by respondents for wet season during 20 years were not significantly different (t = -1.27). A little percentage of respondents (1.9%) did not sell rice in 2000 and 0.6% in 2018. Most of the respondents (86.9%) sold 1 to 15 tons of their rice in past and present. A little change of respondents was found in different amounts of selling rice over 15 tons during 20 years (Table 4.87).

Average amount of rice sold by respondents for dry season were 12.5 tons and 18.3 tons in past and present respectively. Changes of selling amount of rice for dry season sold by respondents during 20 years were highly significantly different (t = -5.29). More than half of the respondents 68.1% sold 1.1 to 20 tons in past and in present these amounts of rice was sold by 70% of respondents. In past, 20.1 to 40 tons of rice was sold by 16.3% of respondents and these percentages increased to 21.3% in present. The percentage of the respondents who sold their rice 40.1 to 60 tons increased from 1.9% in past to 3.1% in present. Only 0.6% of respondent sold their rice 60.1 to 80 tons in past and increased to 3.1% in present. In 2018, 0.6% and 1.3% of respondents could sell 80.1 to100 tons and over 100 tons of rice, respectively (Table 4.88).

### 4.1.6 Most expensive activities for rice production

The most expensive activity of respondents was the crop establishment cost in rice production at past and those percentages of respondents (43.1%) decreased to 15.6% in present. In past, the most expensive activity was fertilizer costs and that percentages of respondents increased to 69.4% in present. Harvesting cost of rice production was the most expensive activity said by the respondents (25%) in past and decreased to 15% in present (Table 4.89).

**Table 4.86 Market condition for rice in both seasons between 2000 and 2018 in Mawlamyinegyunn Township**

| Market condition | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Intermediary on farm | 24 | 15.0 | 24 | 15.0 |
| Intermediary in market | 5 | 3.1 | 5 | 3.1 |
| Milling company | 124 | 77.5 | 125 | 78.2 |
| Not selling | 2 | 1.3 | 1 | 0.6 |
| Others | 5 | 3.1 | 5 | 3.1 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.87 Selling amount of rice for wet season between 2000 and 2018 in Mawlamyinegyunn Township**

| Selling amount of rice (tons) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No selling | 3 | 1.9 | 1 | 0.6 |
| 1-15 | 139 | 86.9 | 138 | 86.3 |
| 15.1-30 | 16 | 10.0 | 18 | 11.3 |
| 30.1-45 | 2 | 1.2 | 2 | 1.2 |
| Over45 | - | - | 1 | 0.6 |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 7.8 | | 9.1 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 32.8 | | 56.0 | |
| t value | $-1.27^{ns}$ | | | |

ns = non significant , n=160

**Table 4.88 Selling amount of rice for dry season between 2000 and 2018 in Mawlamyinegyunn Township**

| Selling amount of rice (tons) | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No selling | - | - | 1 | 0.6 |
| 1.1-20 | 109 | 68.1 | 112 | 70.0 |
| 20.1-40 | 26 | 16.3 | 34 | 21.3 |
| 40.1-60 | 3 | 1.9 | 5 | 3.1 |
| 60.1-80 | 1 | .6 | 5 | 3.1 |
| 80.1-100 | - | - | 1 | 0.6 |
| Over100 | - | - | 2 | 1.3 |
| No summer rice farmers | 21 | 13.1 | - | - |
| Total | 160 | 100.0 | 160 | 100.0 |
| Mean | 12.5 | | 18.3 | |
| Minimum | 0.0 | | 0.0 | |
| Maximum | 61.6 | | 102.7 | |
| t value | -5.29*** | | | |

***= significant at 1% level, n=160

**Table 4.89 Most expensive activity for rice production between 2000 and 2018 in Mawlamyinegyunn Township**

| Most expensive activity | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Establishment | 69 | 43.1 | 25 | 15.6 |
| Fertilizer | 51 | 31.9 | 111 | 69.4 |
| Harvesting | 40 | 25.0 | 24 | 15.0 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

### 4.1.7 Non farm income and remittances

Most respondents (74.4%) did not have another source of income apart from agriculture in past and decreased to 63.7% in present. In past, another source of income apart from agriculture was obtained by 25.6% of sample respondents and increased to 36.6% in present. Most of the respondents (99.4%) did not usually obtain remittances from abroad in past and decreased to 98.8% in present. The percentages of respondents who usually received remittance from abroad increased from 0.6% in past to 1.3% in present (Table 4.90).

### 4.1.8 Climate constraints

One third of the total respondents' rice fields were flooded in 2000 and in 2018 only 12.5% of the respondents faced these problems. Respondents (51.2%) did not face serious climate change during rice production in past and increased to 60% in present. Rain damages at harvesting time were encountered by sample respondents (15.6%) in past and 27.5% of the respondents faced these events in present (Table 4.91).

**Table 4.90 Another source of income apart from agriculture and remittances from abroad obtained by respondents between 2000 and 2018 in Mawlamyinegyunn Township**

| Another source of income | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| No | 119 | 74.4 | 102 | 63.7 |
| Yes | 41 | 25.6 | 58 | 36.3 |
| Total | 160 | 100.0 | 160 | 100.0 |
| **Remittances** | | | | |
| No | 159 | 99.4 | 158 | 98.8 |
| Yes | 1 | 0.6 | 2 | 1.2 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

**Table 4.91 Serious climate encountered by respondents for rice production between 2000 and 2018 in Mawlamyinegyunn Township**

| Serious climate | Respondents | | | |
|---|---|---|---|---|
| | (2000) | | (2018) | |
| | Frequency | Percentage | Frequency | Percentage |
| Flood | 53 | 33.2 | 20 | 12.5 |
| No serious climate | 82 | 51.2 | 96 | 60.0 |
| Rain damage | 25 | 15.6 | 44 | 27.5 |
| Total | 160 | 100.0 | 160 | 100.0 |

n=160

## 4.2 Discussion

### Farm holding

In study area, changes of total farm size of the respondents during 20 years were not significantly different ($t = -1.21^{ns}$), however, numerically increased (3.3 to 3.6 ha) between 2000 and 2018. Although a study area was affected by Cyclone Nargis on May 2008, rice areas were not noticeably decreased because it was not seriously affected. Dry season rice program was introduced on a large scale in 1992-1993, all respondents could grow double rice crop a year in 2018.

### Wet season

### (a)Varietal changes

Regarding wet season rice, all respondents used traditional varieties in both 2000 and 2018; but they changed to use Paw San rice variety instead of Hnangar variety because of attractive price and good eating quality. In the saline coastal area of the Delta, the local rice variety, Hnangar, was the most commonly used. It is photosensitive with very poor yield, but it has a moderate tolerance of salinity (~4 $dSm^{-1}$) and submergence. Moreover, it is also tolerant to Ufra disease (nematode is a serious problem), and has good dormancy, with short slender type. Many farmers in the lower Delta preferred to grow Hnangar for these reasons (LIFT, 2013). Local varieties, including Paw San rice were often preferred by farmers during the monsoon season especially in areas that are prone to flooding (Myint & Napasintuwong, 2016). Paw San Yin, a fragrant variety produced in the delta, can fetch double price of higher yielding semi-dwarf type. More date trading by individual varietal names has increased since the 1990s (Okamoto, 2005). Ninety seven percent of respondents used farm saved seeds for rice production in 2000. Rice farmers were still using their own seeds more than from other sources such as DOA that produces certified seeds or seed shops (Myint & Napasintuwong, 2016). In 2018, there were only 19% of the respondents used certified seeds of Paw San rice because certified seeds of this variety was not enough for requirement distributed by DOA and private seed companies. Since the formal sector seed supply mechanism was not fully functional, the DOA was not able to produce enough certified seeds to meet farmers' demands. The DAR was in turn unable to produce enough registered seeds as required by the DOA (LIFT, 2014). Eighty percent of respondents obtained varietal information from farmers to farmers in 2000, whereas in 2018, 17% of respondents received information from extensionists.

**(b) Changes in tillage operation and crop establishment**

Land preparation was done by using animal drawn implement in 2000 and changed to use machine because farm machineries utilization has been accelerated since the summer rice was introduced on a large scale in 1992-1993. More than half of the respondents practiced three strokes of tillage operation in 2000 and continued this practice by 33% of respondents and the rest 67% of respondents changed only two strokes of operation due to traditional farming to mechanized farming. In the study area, rice was usually established by both transplanting and broadcasting methods. According to the results, most of the respondents used 30 to 45 days seedlings in transplanting method in 2000 and this practice was not changed because the study area was deep water area. Transplanting was the most common method for wet season rice establishment, giving the rice plant a competitive advantage over weeds. Average use of family labor for manual transplanting was (2 person $ha^{-1}$) in 2000 and it was not significantly changed in 2018. Changes of hired labour used by 93.7% of respondents for transplanting in wet season during 20 years were highly significantly different. Moreover, one fifth of total respondents used more hired labour as rice fields became boggy due to successive growing of rice. Main source of water was rainfall and keeping permanent flooding in their fields. Therefore, no changes were found between 2000 and 2018 because they could not control water level due to heavy rain in deep water area.

**(c) Crop management practices**

In both wet and dry seasons, organic fertilizer was not used by 49% of the respondent in 2000. In 2018, the respondent who did not use organic fertilizers markedly increased to two times (98%) because they did not use animal drawn implements and their fields might be fertile due to silt and organic sediment of river water. Although chemical fertilizers were not used by sample respondents (89%) in 2000, 55% of them used little amount of fertilizers in 2018. In the study area, fertilizer applications used by sample farmers were apparently lower than the recommended rate (57.5kg N $ha^{-1}$, 12.7 P kg $ha^{-1}$ and 15.6 K kg $ha^{-1}$) because study area was continuous flooding and local varieties might be generally less responsive to fertilizers. Between 2000 and 2018, weed control was not practiced due to continuous flooding and also this condition might be suppressed weeds. Pest and disease controls were not practiced in both seasons 2000, but in 2018, changed to use chemical insecticides due to pest infestation.

In wet season, harvesting of rice was done by manually in 2000 and 2018, because it was not feasible to use combine harvester. Although use of family labour (2 person $ha^{-1}$) for manual harvesting was significantly decreased to (1 person $ha^{-1}$), hired labour usage were significantly increased from (14 person $ha^{-1}$) to (16 person $ha^{-1}$). As much as 50% of respondents operated traditional trampling done by cattle as well as by machine in 2000. Only mechanical thresher was used by almost all respondents in 2018 because they did not use animal. Concerning with yield, wet season rice yield increased from 2.8 ton $ha^{-1}$ to 2.9 ton $ha^{-1}$ in 2000 and 2018 because of improvement and management practices.

**Dry season**

**(a)Varietal changes**

In dry season, all respondents used improved varieties (Theehtetyin) in both 2000 and 2018 because this variety had high yield, shorter duration and having fair price. In most cases, HYVs, such as Theehtetyin, a selection of IR 13240, was cultivated as summer rice (Township offices of MAS in Labuta and Phyapon). The photoperiod-insensitivity and early maturation of these high yielding varieties could have been the preferred characteristics for the summer season, rather than the higher productivity (Matsuda, 2009). Seventy eight percent of respondents used non- certified seeds in 2000, but 54% of them changed to use certified seeds because the introduction of certified seed was more and more increased in 2018 by DOA, JICA project and private seed companies. Source of varietal information was obtained from fellow farmers in 2000, while half of respondents received varietal information from extensionists by demonstrating in farmer fields with demonstration plots and by seed production training and educational programs.

**(b) Crop establishment**

Overall respondents used broadcasting method in 2000 and it was not changed in 2018 because this method reduced labour requirement and also less time consuming. Thus, farmers tried to overcome labour scarcity by changing farming practices, such as seed broadcasting instead of transplanting in rice cultivation (Htway et al., 2014). Use of family labour (1 person $ha^{-1}$) for seed broadcasting was significantly increased to (2 person $ha^{-1}$). And also, average hired labour used for seed broadcasting was significantly different from 1 to 2 person $ha^{-1}$. Most respondents (78%) used stream or river by supplying water pump in 2000 and increased to 92% of respondents because dry season rice in the delta was usually irrigated by pumped water.

**(c) Crop management practices**

Although (75%) of the respondents used chemical fertilizer in 2000, all respondents used in 2018. Not only use of chemical fertilizer but also amount of fertilizes rate was markedly increased compared with the past. In the study area, sample farmers applied chemical fertilizers two times increase than the recommended rate (57.5 N kg $ha^{-1}$, 12.7 P kg $ha^{-1}$ and 31.2 K kg $ha^{-1}$) except potassium fertilizers. The use of chemical fertilizers for dry season in delta during early 1990s was estimated to be relatively higher than that for wet season cropping based on the data of the 1995 field survey conducted by (Takahashi, 2000). Three times of split fertilizer application used by 35% of respondents in 2000 changed to use this practice by 76% because respondents knew about agricultural practices from extensionists and other sectors, (NGOs). And also average family labour and hired labour used for fertilizer applications were significantly increased within 20 years due to split application practice and more use of chemical fertilizers. Although weed control was not practiced by 60% of respondents in 2000, 84% of the respondents made weed control by using chemical herbicide in 2018. Pest and disease control was not done in 2000, but changed to practice this control by using chemical insecticide for pest infestation.

**(d) Harvesting and yield**

Harvesting of rice was done by manually in 2000, and in 2018, the respondents changed to use combine harvester. One machine may easily harvest more than 10 acres of paddy a day if farms are close to each other. Machines are efficient and can also reduce waste. They only require three workers including a driver for harvesting an acre of paddy. Changes of rice yield $ha^{-1}$ for dry season during 20 years were highly significantly different (t = -7.95***). Rice yield increased from 3.9 to 5 ton $ha^{-1}$ because they used large amount of chemical fertilizers, quality seeds and combined harvester in which losses were little compared with manual harvesting. Since Cyclone Nargis devastated large parts of the Ayeyarwaddy Delta in May 2008, total rice production and productivity (yield $acre^{-1}$) have gradually recovered. It was observed that many implementing partners in the Delta providing extension education to farmers about good agricultural practices (GAP), delivered primarily through the Farmer Field Schools (FFS) approach. Extension education topics typically focused on crop production technologies and high yielding seed varieties (LIFT, 2013).

**Post- harvest activities for both seasons**

Because of increased production at present, average selling amount of rice was increased compared with the past. Between 2000 and 2018, dry season rice was not stored for home consumption because this variety has not good eating quality like Paw San. Respondents (48%) used rice straw for animal feeding in 2000, whereas in 2018, 46% of respondents burned rice straw in the field and some respondents (36%) incorporated straw in the soil. The reasons for changes were that they did not use draught animal and already getting of organic manures in their fields. Most of the respondents dried their harvested rice by sun before selling in 2000 and 2018 because they were unable to obtain a price premium for well dried grain. And also they used hired and non-hired labours for post-harvest activities such as drying and storage etc. Regarding with market conditions, majority of the respondents sold their dried rice to milling company between 2000 and 2018. More than half of the respondents did not face serious climate change during rice production.

# CHAPTER V
# CONCLUSION

The present study emphasized on the changes of rice production system in the study area between 2000 and 2018. This study was conducted to understand the changes of rice areas and the operation of cultivation practices such as variety, land preparation, establishment methods, use of chemical fertilizers, weed control method, harvesting method, and rice yields etc.

Based on the results of this study, there was no apparently affected in Mawlamyinegyunn Township even though the Cyclone Nargis had hit seriously in 2008. And then all respondents cultivated dry season rice after introducing summer rice programs at 1992-1993. It was found that the machines were widely used by all respondents in land preparation in 2018 in spite of using animal drawn implements. In the aspect of the seeds sector, although half of respondents changed to use certified seeds (CS) (Theehtetyin) only for dry season, they used Paw San rice as the farm saved seeds in wet season and that was suitable for local conditions and had good in eating quality and better price than others. In the study area, certified seeds were more distributed by DOA, JICA projects and other sectors in 2018. Studying up the methods of establishments, transplanting and broadcasting methods for wet and dry season found that there were not changed between 2000 and 2018. But use of family labour and hired labour for manual transplanting were increased in 2018. In the practices of care and management, chemical fertilizers, chemical insecticides and herbicides were widely used than before especially for dry season. In harvesting, the study found that harvesting was reaping by using combine harvester in 2018 although it was harvested by man power before. Concerning with yields, it was observed that, rice yields were substantially increased in both seasons.

According to the results, rice yield were increased due to improvement of management practices such as use of certified seeds, more chemical fertilizers with split application, insecticide and herbicide applications and combine harvester especially in dry season. And also varietal changes was occurred in wet season such as Paw San rice which has better price and good eating quality. In addition, certified seeds were changed to use because DOA, seed companies and NGOs produced large amount of certified seeds than before in dry season. Management practices were changed due to intervention of extension activities by DOA on utilization of quality seeds, split fertilizer application, pesticide and herbicide application. When high demand on labour at peak season and

scarcity of labour led to changing from traditional method to mechanization in the study area.

In the study area, some changes were found between 2000 and 2018, however, prominent changes in wet season rice production system were not observed except mechanization changes in this study. Therefore, based on this study, policy makers and all stakeholders involved in rice value chain should be taken into consideration of some recommendations for improving rice production system in delta region.

**Suggestions**

1. To support all farmers for the establishment of modern mechanized farms including irrigation canal and drainage system in land consolidation
2. To encourage application of quality seeds by farmers participation in seed production programs which would be promoted by the DOA in collaboration with private sectors and NGOs
3. To provide training and educational programs for all farmers on seed production, capacities in mechanization and GAP by DOA and other concerning institutions
4. It is needed to coordinate between public and private sectors in order to available combine harvester and machines in time for farmers

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