EVALUATION OF BALANCED MACRONUTRIENT AND MICRONUTRIENT FERTILIZER APPLICATION IN RICE CULTIVATION

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OCTOBER, 2019

EVALUATION OF BALANCED MACRONUTRIENT AND MICRONUTRIENT FERTILIZER APPLICATION IN RICE CULTIVATION

A thesis presented by

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to

The Post-graduate Committee of the Yezin Agricultural University as a requirement for the degree of Doctor of Philosophy in Soil and Water Science (Soil Science)

Yezin Agricultural University

OCTOBER, 2019

The thesis attached hereto, entitled "**Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation**" 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 requirement for the degree of Doctor of Philosophy (Soil Science).

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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 Than Shwe and Daw Khin Yonn

ACKNOWLEDGMENTS

It is my proud privilege to express sincere gratitude to Dr. Myo Kywe, emeritus Rector and Chairman of National Education Policy Commission for his encouragement, motivation, and initiation this Research-Based Ph.D. program for all of us.

I also thank Dr. Nang Hseng Hom, Rector of Yezin Agriculture University, Dr. Kyaw Kyaw Win, Pro-rector (Administration) and Dr. Soe Soe Thein, Pro-rector (Academic) for the inspiring guidance, keen interest, activeness, and sharpness. I take this opportunity to express my deep and sincere feeling of gratitude to them for suggesting research topic, valuable guidance, constant inspiration, constructive criticism in preparation of the manuscript of this dissertation.

I would like to express thanks to my supervisory committee Dr. Kyaw Ngwe, Professor of Department of Soil and Water Science, Dr. Kyaw Kyaw Win, Pro-Rector (Admin.) and Dr. Swe Swe Mar, Lecturer of Department of Soil and Water Science, YAU for their continuous guidance, inspiration, motivation, and constant encouragement familiarly.

I also would like to express my gratitude again to my external examiner Dr. Myo Kywe, for valuable guidance, comment, and suggestion for the perfect of my dissertation.

I would like to express my most profound and heartiest (no word to express) gratitude to U Soe Win, and beloved work-family Daw Khin Win Mar, Daw Khin Mar Myo and all of our Land Use staffs, Department of Agriculture for constant inspiration and valuable support throughout my study. It is a great pleasure to acknowledge my junior officer U Tun Tun Linn (Township manager of Pyinmana) for his invaluable and energetic support. Words are not enough for expressing my heartiest gratitude towards rendered help of his enthusiastic encouragement and physical and moral support during my research work.

I am grateful to Dr. War War Khin and Daw Thuzar Win who assist in writing manuscript, not only swiftly and accurately, but cheerfully.

Last not the least, my thanks to convey to my beloved daughter Yun Lay for her inspiration throughout my life.

Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation

ABSTRACT

While the crops require macronutrients N, P and K essentially for its growth and yield, furthermore, other nutrients such S, Zn, and B also become crucial for crop productivity since high cropping intensity was adopted in modern agriculture. Both of macronutrient and micronutrients are need to be considered for increasing crop productivities and long term yield sustainability with balanced fertilization. Therefore, these studies were carried out with three objectives as (1) to investigate the individual effect of S, Zn and B on rice cultivation; (2) to assess the combined effect of these nutrients and (3) to study their effect and efficiency based on location in rice growing area of Naypyitaw region. The experimental design was a randomized complete block design, eight treatments with three replications. The treatments were as (1) NPK (2) NPK +S (3) NPK+ Zn (4) NPK +B (5) NPK +S and Zn (6) NPK +S and B (7) NPK +Zn and B (8) NPK +S, Zn and B and the cultivar used in these experiments was Yadanatoe. The study schedule was surveyed study and conducted two pot experiments and two field experiments on Pobbathiri and Zeyarthiri Townships (Ottrathiri District). The applied nutrients were 30 kg S, 5 kg Zn, and 3 kg B ha^{-1} and blanket fertilizer rate were 85 kg N, 13 kg P and 30 kg K ha^{-1} in all experiments. Fertilizer P, S, Zn and B were applied at basal but N and K were applied two time equally split at 14 and 42 DAP. As observation, the nutrient level of the study area was deficient in S and Zn, and B in somewhere depend on location and based on the fertilizer management. All of the pot and field experiments showed, filled grain %, and yield among the treatments were significantly different. Yield responses of nutrient in these experiments were 6-40% by S, 2-16% by Zn and 4-17%by B and the highest attainable yields were achieved 8-80% over treatment of NPK only with combined application of all nutrients based on the original soil. In two combination treatments, the effect of (NPK+ Zn and B) combination was found prominently. According to the research findings, utilization of nutrient decreased 30 percent in nitrogen ,10 percent in phosphorus and about one percent in potassium by combined nutrients (S +Zn +B) for the same yield resulting in saving NPK rate and enhancing better nutrient management with balanced fertilization in rice cultivation. This study revealed how the tested nutrients (sulphur, zinc and boron) have positive effects on the rice yield and increased macronutrient’s efficiency and thus application of macronutrient and micronutrients fertilizer is strongly recommended for sustainable development of rice production in Naypyitaw areas.

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CHAPTER I
INTRODUCTION

While 795 million people of the world population still suffer from hunger, more than two billion suffer from micronutrient deficiencies or forms of over nourishment (Food and Agriculture Organization [FAO] 2015). Fifty percent of world population suffer from micronutrient deficiency and most of the plant nutrients are essential for human health, (FAO, 2000). Major food of human is cereal and among them rice is the third most important cereal crop after wheat and corn. It is a staple food for more than half of the world population (Fageria, 2007). Sixty percent of the world population depend on rice as a staple food (Win, 2003). Rice has played a vital role in human's primary lifeblood throughout the history of humankind. It is the most critical food grain for millions of people, especially in Asia, Africa, and Latin America. Therefore, increasing rice production is one of the major options for eradication of hunger (FAO, 2000).

More than a hundred countries with a total area of about 160 million hectares are grown rice and producing more than 700 million ton every year (International Rice Research Institute [IRRI] 2010). About 1 billion households depend on rice cultivation for employment and their primary source of livelihood (Shimamura, 2005). The Ninety-Five percent of total world rice growing areas are in developing countries, including Myanmar (IRRI, 1995). Myanmar is one of the top ten countries producing rice in the world (Win, 1991).

Myanmar was the largest rice export country in the world in 1940. Also, sixty-five percent of the total population engaged in the agricultural sector in Myanmar today. Of them, seventy-five percent depend on rice. (Ministry of Agriculture, Livestock and Irrigation [MOALI] 2015). The rice industry is a broad spectrum which is not only a provider to the livelihood of rural people but also a source of income for other categories in Myanmar. In Myanmar, 37.23% of total cultivable land area and 54.8% of agricultural land are occupied by rice growing and production of 28.19 MMT with an average yield of 3.94 ton ha^{-1} (Win, 2012). The world population is increasing with time, and it will be from the current status of 7.0 billion to 9.4 billion by the year 2050 (United State Census Bureau, 2012). Therefore, increasing rice production is necessary to ensure food security as the population increases. While the area of cultivable land is limited to expand in the world, yield increasing is getting the basic option in agricultural sector, including Myanmar.

According to the international organization's survey, rice yield in Myanmar is still low if compared to that of the key production area of Asia countries (World Bank Groups [WBg], 2016).When we attempt to increase rice production, factors affecting increased yield are mainly observed in the varietal improvement and agronomic practices, including water management, pest management, and nutrient management. Among these factors, fertilizer management plays a crucial role. Lu and Shi, (as cited in Fageria, 2009) stated that the chemical fertilizer contributes to grain yield increased up to fifty to sixty percent in China. The use of chemical fertilizer and soil fertility improvement are important strategies to achieve food production at a desired level and security. Baligar, Fageria, and He (2001) pointed out that as much as half of rice yields during the Twenty century is resulting from the use of fertilizers.

In recent years, the state took an intervention on crop production, including input distribution and purchasing crop since the planned economy was adopted in the country aligned with socialist infrastructure in Myanmar. The use of input such as fertilizer and required pesticide was encouraged with subsidy program by the state, but it has not met insufficient level at all nutrients for all crops grown in the whole country. After the socialist government, the state control mechanism was removed and let the private sector contribute to the distribution of inputs as the market-oriented economic system is adopted. Since from that time, the use of fertilizer by farmers cannot be controlled by the state agency. Generally, Myanmar farmers used to apply much less in kinds of fertilizer and much less amount in all nutrients than plant's needs, resulting in depleting of fertility in their soil and enhancing low productivities. The use of insufficient fertilizer rate with inappropriate nutrient composition is reflecting less profit with low Partial Factor Productivity (P.F.P). While the neighboring countries; Thailand and Vietnam have P.F.P value 72 kg, Myanmar has only that of 30 (WBg, 2016).

Pattanayak, Mukhi, and Majumdar (2008) stated that application of inadequate and unbalanced nutrient is one of the major factors responsible for low productivity. Balanced nutrient management provides an opportunity for not only crop productivity but also assistance in the rebuilding of soil organic matter (Rusinamhodzi, et al., 2014). Liebig (1873) also revealed out the requirement of all nutrients for the yield of plants since in Nineteen century. The imbalanced and inadequate nutrient are inhibiting for the efficacy of major and other minor nutrients too. Agricultural production and productivity are directly linked with nutrient availability and uptake by growing plants. The application of all essential nutrients is required for all crops to sustain soil fertility for high crop yield.

Also from the sustainability point of view, nutrient management ideally should provide a balance between nutrient input and output (uptake and losses) over the long term to maintain soil fertility level (Bacon, Lanyan & Schlander, 1990). Insufficient supply of fertilizer or nutrient will result in negative fertility level in productive land.

On the other hand, while area expansion is limited to expend the crop growing area to meet food security, trying to increase of cropping intensity might be standard practices for increasing population. It may result in more or less fertility depletion in cropland and thus provision of insufficient indigenous nutrient to growing crop by soil occurs.

In the agricultural sector, the use of N, P, and K fertilizer has been initiated with appropriate technologies for crop yield increased since the past six decades. Fertilizer application at the right time, right source and right dose have been developing in Myanmar since that time. Currently, Site-Specific Nutrient Management program me are being driven in the farmer field through omission techniques. A lot of experiments and demonstrations have been developed and achieved a lot in most of major rice growing area. The result of omission and addition plots from SSNM experiment indicated some area of rice field required not only NPK but also other nutrients such as S and Zn too (Land Use Division, Department of Agriculture, 2015).

However, while plants take up all essential elements, the application of just three major elements would not be enough for long term sustainability and enhancing the multi-nutrients deficiency in rice. Swrup and Ganeshamurthy (1998) stated that nutrient deficiencies are restricted not only by N, P, and K but also by S, Zn and Boron. Because of increased cropping intensity in rice field, especially in irrigated land, the deficiency of minor elements becomes a severe problem day by day. At present, sulphur, zinc, and boron become a vital role in rice cultivation. Not only macronutrient but also micronutrient can increase productivity and efficiency in the crop by balanced ratio. It is still needed to study the micronutrients. How much deficient these nutrients on rice field and how much effect on rice production by these nutrients together with macronutrients (NPK) are attractive option for rice cultivation.

Therefore, these studies were conducted with the three objectives; to investigate the individual effect of sulphur, zinc, and boron, to access the combined effect of these nutrients and to study the effect and efficiency of these nutrients on rice based on soil.

CHAPTER II
LITERATURE REVIEW

2.1 Rice Production in Myanmar

Given the global market of rice is multiplying, it is essential to produce more rice in different rice growing ecosystem to feed for increasing world population. Also, it is estimated that need to produce 60% more than the current situation to meet the food demand of the world population by the year 2030 (FAO, 2015). It is clear without question that the knowledge of rice production technology is required for the whole world.

Being an Agricultural country, Myanmar tries to develop the Agricultural sector through increased crop productivity. Among the two approaches to achieve crop productivity, where there are limited in land for area expansion, trying to the increased yield is more common in the Agricultural sector. A central pillar of increased yield is varietal improvement, agronomic practices, systematic nutrient supply and protection of pest and disease and post-harvest losses. Rice production in Myanmar is aim not only for local consumption but also to earn export money. Average per capita consumption in Myanmar is 155 kg per year, so the total union rice consumption is about 8 million metric ton per year. The total rice consumption based on year was described in Figure (2.1).

Being the staple food of Myanmar, rice consumption is increasing year by year as the population increases. Rice growing area in Myanmar is almost stable during three-decade from 1960 to 1990, and it increased steadily up to 2010 (Ricepedia.org/MM, 2013). It can be seen in Figure (2.2). The average rice yield in the growing county in the world varies from less than 1 t ha^{-1} to more than 6 t ha^{-1}. The average return of Myanmar is 1.8 t ha^{-1} while China has 3.5 t ha^{-1} in 1974-76 (Yoshida, 1981).

However, the yield of Myanmar is increasing year by year since when adoption of the high yielding technologies with improved varieties throughout the country (Thu, 2012). The yield of rice in Myanmar from 1960 to 2014 was shown in Figure (2.3). The increased rice area after 1990 may be due to the adoption of double cropping system in rice of Myanmar. Rice is usually grown twice a year if the water is available. Effective planted area of rice is increasing gradually from 5 million ha in 1984 to 8 million ha in 2014 (Ricepedia.org/Myanmar, 2013).

After green revolution, about1960s world rice production increased significantly. Meanwhile, the high yielding campaigns of every township program in the whole country were implemented in Myanmar, resulting rice production was increased considerably too.

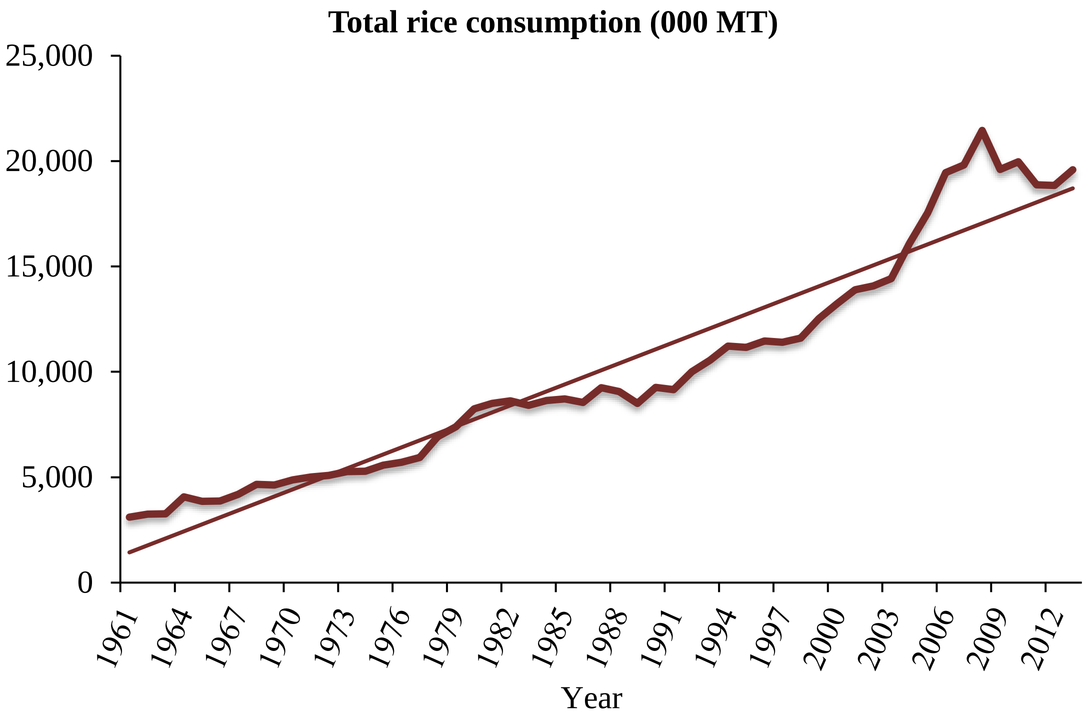


Figure 2.1 Total Rice consumption with year in Myanmar

Source- Ricepedia.org/ Myanmar (2013.)

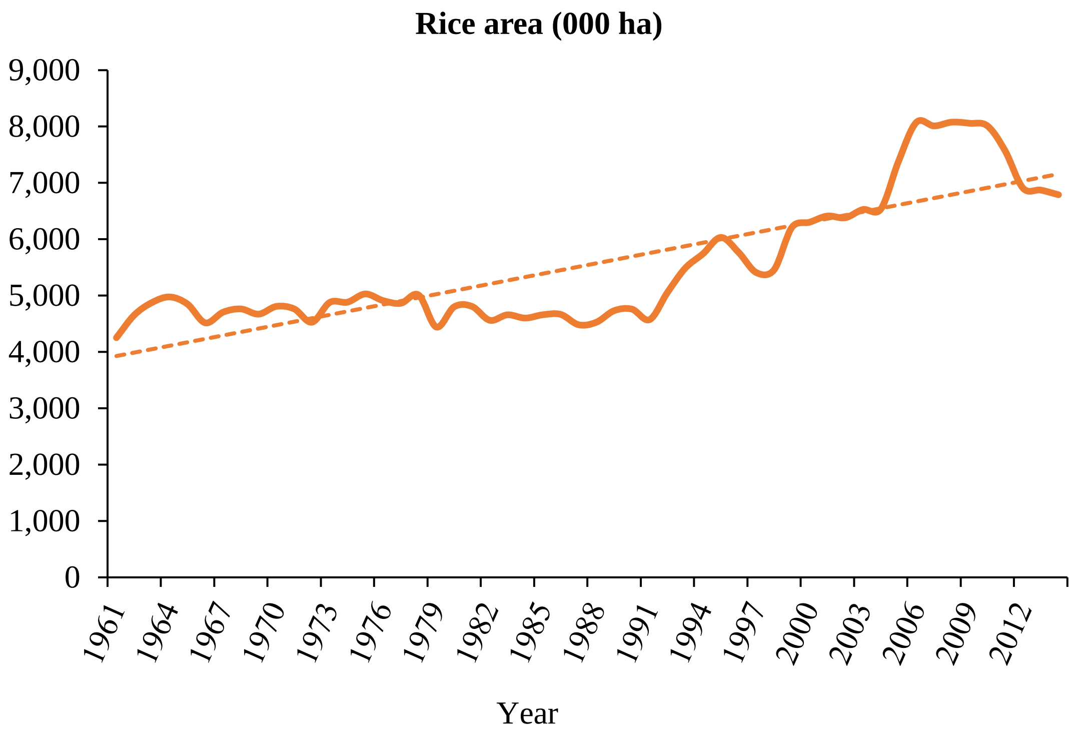


Figure 2.2 Rice growing area in Myanmar (1961-2013)

Source: Ricepedia.org/Myanmar (2013).

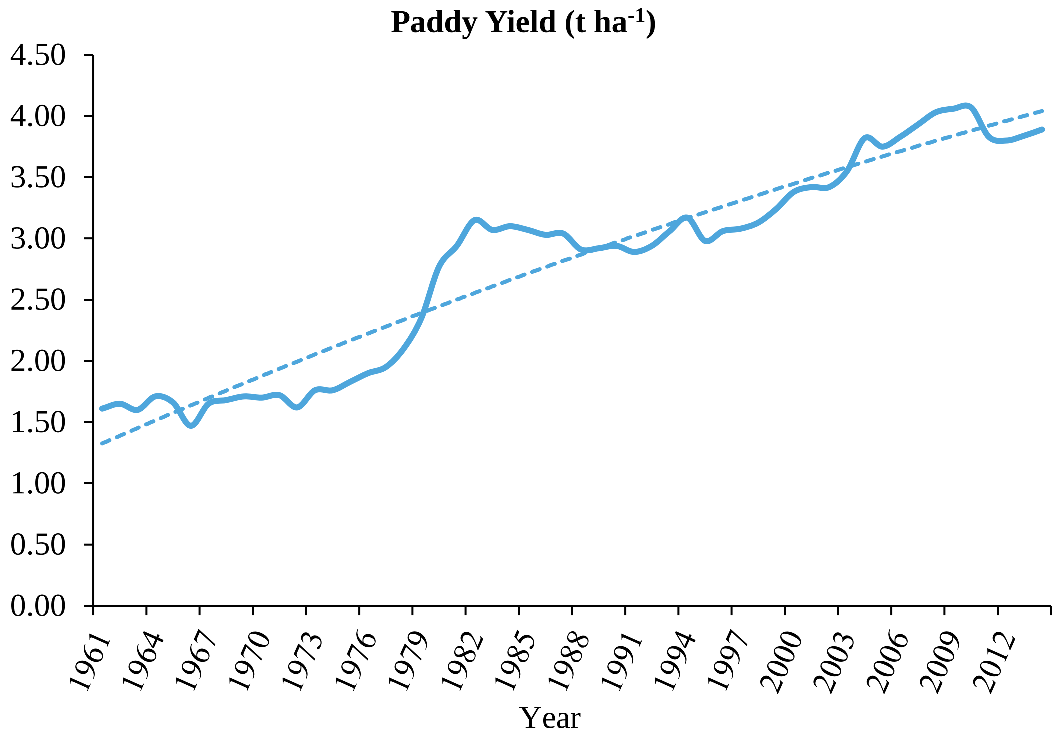


Figure 2.3 The yield of rice in Myanmar (1961-2013)

Source: Ricepedia.org/Myanmar (2013).

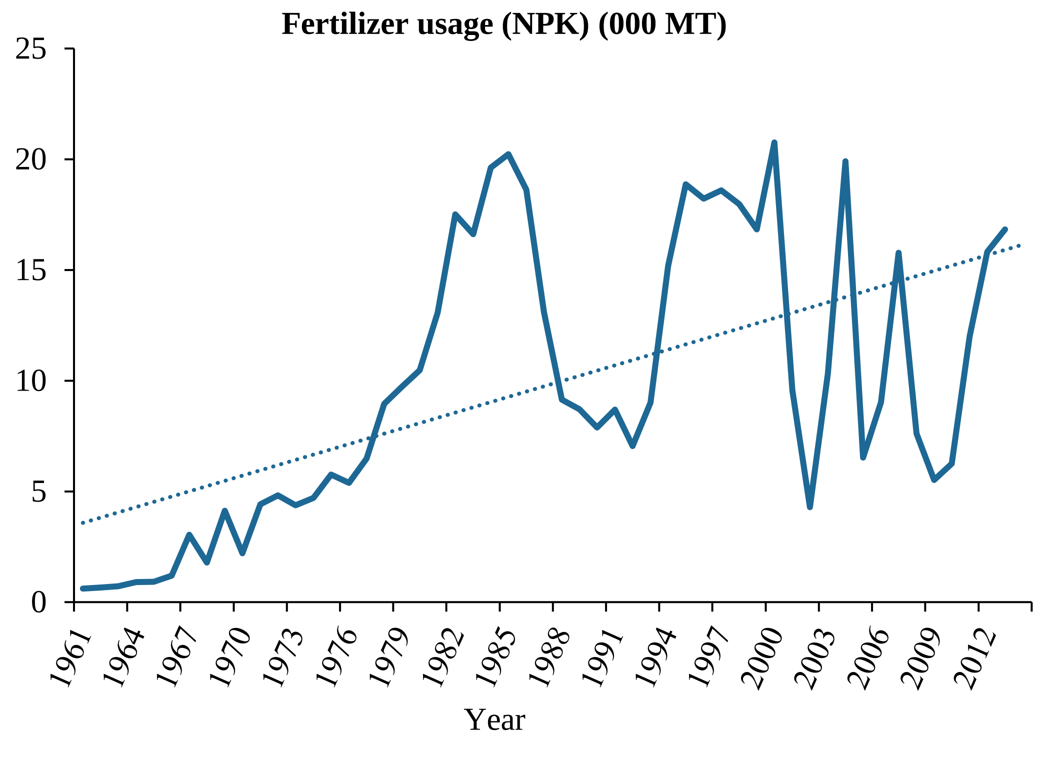


Figure 2.4 Fertilizer usage in Myanmar (1961-2013)

Source: Ricepedia.org/Myanmar (2013).

Production of rice became increasing due to the introduction of high yielding varieties and availability of extension services with technologies and subsidy program of input, especially in fertilizers. During this time, the use of the modern variety, chemical fertilizers, and systematic rice cultivation methods were accelerated with high momentum. The government encouraged farmers to apply inputs in their field, especially in rice cultivation. After those days, the production of rice in the past two decades became stagnated, although the yield increases steadily in a few. The increased yield of the crop was from 3.54 t ha^{-1} in 2003 to 4.07 t ha^{-1} in 2010 (Win, 2012). Although the target yield of Myanmar is laid down as 5.15 ton ha^{-1}; it has not met yet and the present yield of Myanmar is still low if compared to other's yield. The average of world paddy yield, yield in Southeast Asia, Japan, and Vietnam were 4.31, 4.03, 6.78, and 5.22 t ha^{-1}, respectively in 2008. The main reason for that lower improvement in yield might be due to the effect of less use in fertilizer (Win, 2012).

The yield is reflected with rice ecology also associated with irrigation facility and good socioeconomic condition (Yoshida, 1981), however, the most important technique is nutrient management in crop growing in everywhere to increase the yield of the crop. Fertilizer usage in the country can be seen in the following (Figure 2.4) (Ricepedia.org/MM, 2013). The usage is steadily increased from the beginning to 1985 and then decline to 1993 and increase again and more or less fluctuating at current condition. The average fertilizer use in Myanmar is decreasing and notably very low as average farmers applied only 5 kg NPK per ha for arable land in 2009 which is one fourth that of 1995 (FAOSTAT, 2012). Although the farmers become aware of fertilizer in current condition, most of them applied macronutrients only, but required nutrients of crops and removal by the plant were never considered for sustainability in their land.

Fertilizer application was introduced since the mid 20 century in Myanmar, but the usage has not been matched systematic approaches yet. Only major nutrients, primarily nitrogen, is used to be applied in most of their lands. Growers ignored other nutrients especially in micronutrients, and they never noticed the deficiency of those nutrients until recent years.

The basic technique of systematic nutrient management is balanced fertilization that is to be applied for the nutrient to meet the plant's requirement in the right time and the correct dose. Although growers used their land in high intensity, they never noticed the removal amount of nutrient from their land. Their practices made the soil nutrient minus day by day, and finally, it results in nutrient depletion in Agricultural land. At present, it may be significant challenges for crop productivity and its negative effect on future land is too great. Even when soil improved crops are grown, it is still needed to be supplied macronutrient and micronutrient at the right dose at the right time. Because Myanmar is now facing with land degradation by soil erosion and fertility depletion. Major causes of fertility depletion may be due to insufficient apply of nutrient in Agricultural land. The applying of high yielding variety with low input lead to land degrading, yield decreases in the long term and then low income and consequently low invest in inputs at last.

2.2 Fertilizer Application in Rice Cultivation

It is estimated that 60% of cultivated soils have nutrient deficiency or elemental toxicity problem, and about 50% of the world population suffer from micronutrient deficiencies (Fageria, 2009). Moreover, it is estimated that the total use of fertilizer will increase from 133 MM tons year^{-1} in 1993 to about 200 MMT year^{-1} by 2030 to meet the future need for foods (FAO, 2000). Most of the essential plant nutrients are also necessary for human health and livestock production too. Additionally, while we are trying to produce more rice for export, we need to get the world market share. Global market sharing is a challenge with the high nutritional value of crops (FAO, 2000). It is necessary to apply required nutrients sufficiently for high nutritional value to compete and overcome this challenges. From the sustainable agriculture point of view, ideal nutrient management should provide a balance between nutrient input and output over the long term to sustain soil fertility level (Bacon et al., 1990). The removal nutrients by crop or other losses from the system must be replaced annually or at least within the longer crop cycle (Hackman et al., 2003).

Mineral nutrition, along with the availability of water, improved cultivar, control of disease & weeds, and socioeconomic condition of the farmers, play essential roles in increasing crop production (Fageria, 2009). Stewart, Dibb, Johnston, and Smyth (2005) also stated that average percentage of yield attributable to fertilizer generally ranged from about 40 to 60 percent in the US and England and tended to be much higher in the tropical countries in the 20th century. Baligar et al., (2001) reported that as much as half of the increased crop yield during the 20th century derived from the increased use of fertilizer. Similarly, it is recorded that the contribution of chemical fertilizer has reached 50 to 60 % of the total increased grain yield in China, Lu & Shi (as cited in Fageria, 2009). According to Fageria and Baligar (1997), N, P, and Zn were a most yield-limiting nutrient for annual crop production in Brazilian soil.

Increasing crop yield in the 21st century has become an essential component of modern society to keep pace with increasing world population. Global food demand is required to increase by 50% in the next 30 years (FAO, 2017). The upgraded agricultural system should be economically viable, environmentally sound, and socially acceptable without degrading natural resources aiming for sustainability. In this context, application of mineral or organic fertilizer in the adequate amount and proportion is a vital component of modern agriculture.

2.3 Macronutrient N, P, and K

All type of soils are required to be added as a fertilizer for crop production especially macronutrients N, P and K (Clark, 1982). These elements are major essential plant nutrients for increasing crop yield. Among them, nitrogen is the most limiting factor, and its deficiency symptoms can be seen clearly in the crop season. Huber and Thompson (2007) also stated that nitrogen (N) is one of the most yield-limiting nutrients for crop production in the world. It is required in the most significant amount in most crops.

The growers in worldwide apply over 80 million metric tons of nitrogen fertilizers per year to increase crop yields (Epstein & Bloom, 2005). The use of inorganic N fertilizers has a beneficial effect on human health by increasing the yield of field crops and nutritional quality of foods needed to meet dietary requirements and food for growing world populations (Galloway & Cowling, 2002). The main reasons for N deficiency are due to high-quantity uptake by crop and losses by leaching, denitrification, volatilization, soil erosion, and surface run off (Fageria, 2009). Fageria, Slaton, and Baligar (2003) also stated that the use of low rates for high-yielding modern crop cultivars, especially in developing countries, is another cause of N deficiency. Even in the continuing research on N management, average worldwide N use efficiencies (NUE) are reported to be around 50% by Newbould, (as cited in Fageria, 2009) and N recovery efficiency for cereal production is approximately 33% (Raun & Johnson, 1999).

The increase in crop yields due to N application may be associated with an increase in panicles or heads in cereals and the number of pods in legumes (Fageria 2006 & Fageria, 2007). Nitrogen also improves grain or grain weights in crop plants and reduces grain sterility (Fageria & Baligar, 2001; Fageria, 2006 & Fageria, 2007). The plant growth and yield of a crop are higher influenced by nitrogen than any other essential plant nutrient.

The most important factors in increasing yields of annual crops are a balanced supply of essential nutrients. It can be seen not only in rice but also in upland crops.

The increasing N rate increases uptake of P, K, Ca, and Mg in a quadratic fashion in dry bean plants (Wilkinson, Grunes & Sumner, 2000). He also reported that application of N increased uptake of P, K, S, Ca, and Mg, provided from the presence in sufficient amounts in the growth medium.

Other interactions of micronutrients with N may be associated with crop responses to N fertilization. Increase in crop growth with the application of N may increase crop demands for micronutrients, and micronutrient deficiencies may occur (Wilkinson et al., 2000). The use of an appropriate source of N is important for increasing N use efficiency in crop plants. Such practice enhances not only increasing the yield but also reducing the cost of production and environmental pollution.

Since nitrogen is a mobile nutrient in the soil, its application in large quantities at sowing time may result in losing a lot due to leaching or denitrification that split application is generally recommended. First, top-dressing should be done at the time of panicle initiation, and second application may be desirable at about the reduction-division stage, which starts typically approximately one week before flowering. Nitrogen deficiency during this growth stage significantly decreases grain weight and subsequently, grain yields (Fageria, 2009).

While nitrogen is the main contributor to vegetative growth, phosphorus has an essential role in grain formation. Fageria and Baligar (2005a) reported that one of the major problems constraining the development of economically successful agriculture is a nutrient deficiency of P. After nitrogen, phosphorus (P) has more widespread influence on both natural and agricultural ecosystems than any other essential plant element (Brady and Weil, 2002). Phosphorus deficiency in crop plants is a widespread problem in various parts of the world, especially in highly weathered acidic soils (Fageria & Baligar, 1997; Fageria & Baligar, 2001). Applications of phosphate fertilizers now exceed over 30 million metric tons annually in worldwide (Epstein & Bloom, 2005). Soil acidity is one of the key causes of reduced P use efficiency in crop plants as fixation is high. Without an adequate supply of P, a plant cannot reach its maximum yield potential (Fageria & Gheyi, 1999). The role of phosphorus is energy storage and transfer in crop plants. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP), are compounds with high-energy phosphate groups that drive most physiological processes in plants including photosynthesis, respiration, protein-nucleic acid synthesis, and ion transport across cell membranes (Eastin & Sullivan, 1984). P increases tillering capacity in rice, branches in legume. Pot in which did not receive

P fertilization, plant growth and number of tiller were reduced than that of received N and P fertilization (Fageria, 2009).

The best parameter for evaluating nutrient deficiency in a given soil is crop response to applied nutrient. Nutrient availability by the crop is also influenced by soil acidity and hence too acidic and too alkaline soils are extremely deficient in phosphorus for crop production (Landon, 1984). Phosphorus is a mobile nutrient in the plant; hence, P deficiency symptoms first appear on the older leaves. The visual symptoms of a P deficiency are shortage in tiller, stunted growth and purple or reddish color on the older leaves and reduced yield. (Fageria et al., 2003). When P is deficient, cell and leaf expansions are retarded more than chlorophyll formation, thus the chlorophyll content per unit leaf area increases, however the photosynthetic efficiency per unit of chlorophyll decreases (Marschner, 1995). Phosphorus is not a constituent of chlorophyll; hence, the concentration of chlorophyll in P-deficient plants becomes comparatively high, and the leaf color changes from green to dark green. (Fageria et al., 2003). Use of balanced nutrition means supplying other essential plant nutrients in adequate amount and proportion along with P. At balanced nutrition, crop yields are maximized, and P use efficiency improves. Supply of N and K in adequate amounts and ratios along with P is a classic example to promote optimum growth and yield of crops and consequently higher P use efficiency (Fageria, 2009).

As major nutrient NPK are most limiting nutrients in grain, however, K was the least yield-limiting nutrient. P and K are considered next to N as regards its role in modern agriculture (Bao, 1985). Potassium deficiency in crop plants under different agroecosystems is not as common as N and P deficiencies. Furthermore, K deficiency is not as easily identified as N and P deficiencies. (Fageria, 2009). Crop yields have significantly increased in the last few decades both developed and developing countries through the introduction of modern production technologies; as a result, supplies of K in the soils rapidly depleted. Pretty and Stangel (as cited in Fageria 2009) reported that 17% of the total land area in Africa, 21% of the total land area in Asia, and 29% of the total land area in Latin America are K deficient. Most of the K-deficient soils on these three continents are acid savanna soils. Buol, Sanchez, Cote and Granger (1975) estimated that one-fourth of the soils in the tropics and subtropics have a low K status. Fageria (as cited in fageria, 2009) reported that 50%of the Amazon basin was characterized by soils with low K reserves. Fageria (2009) also reported that many soils of the tropical and temperate regions are unable to supply sufficient K to field crops.

On soils where present K levels are considered adequate, the increased use of other fertilizers and production inputs can quickly shift the soil K status from adequate level to deficient level. Soils that contain relatively high levels of available K; however, the low level of K reserves and poor retention capacity, especially on soils with low cation exchange capacity (CEC) and a preponderance of 1:1 clay minerals, combined with higher crop removal, can result in depletion of available supplies after only a few cropping seasons (Pretty & Stangel, as cited in Fageria, 2009). Furthermore, the maximum amount of K is retained in the straw, in many crops (Fageria, 1991). Where this is removed for fodder, fuel, or other uses, the depletion of soil K will be much too rapid. Hence, the supply of adequate K rate for field crop production is essential not only for increasing productivity but also for reducing the cost of crop production, environmental pollution, and maximizing the efficiency of K use.

Potassium plays many vital roles in crop plants, and the essentiality of K has been recognized since the work of von Liebig, a German scientist published in 1840. Fageria and Gheyi (1999) summarized the functions of potassium to increase crop yields. It can increase root growth and improve water & nutrient uptake, reduce lodging, maintain turgor, which enhances reducing water losses and retard crop diseases. When it is deficient, the plant may susceptible to pest and disease attack. Although K is not a constituent of chlorophyll, a characteristic symptom of K deficiency is the destruction of chlorophyll. It may be K has relation to the formation of chlorophyll precursor or the prevention of the decomposition of chlorophyll (International soil Fertility Manual, 1995). Not only can K increase the resistance of plant tissues, but it may also reduce fungal populations in the soil, reduce their pathogenicity, and promote more rapid healing of injuries (Huber & Arny, 1985).

Potassium, like N and P, is highly mobile in plant tissues that K deficiency symptoms first appear in the older leaves. Potassium deficiency symptoms show up as scorching along leaf margins of older leaves. Potassium-deficient plants grow slowly with poorly developed root systems, weakness in stalks, and appearance of lodging. When it is deficient, the plant may susceptible to pest and disease attack (International soil Fertility Manual, 1995). Interaction of potassium with other nutrients is an important aspect of improving crop yields. Positive interactions of K with N and P have been reported by Dibb and Thomson (1985).

Antagonistic interaction between K and Mg and Ca uptake has been widely reported by many authors (Dibb & Thompson 1985; Fageria 1983; Johnson, Edwards & Lonergan 1968). Furthermore Fageria (1983) also reported that reduction in Ca uptake with increasing K concentration in the growth medium was closely associated with increased uptake of K, indicating that there may have been a competitive effect. A competition between K and Ca and Mg due to physiological properties of these ions has been reported by Fageria (1983) and Johnson et al., (1968). Potassium and micronutrient interactions have been observed with many crop plants. Gupta (1979) and Hill and Morrill (1975) reported that high K rates reduced B uptake and resulting in B deficiency in crop plants. Dibb and Thompson (1985) reviewed the interaction between K and Cu in crop plants are reported that Cu uptake increased with the addition of K. In a review report of Dibb and Thompson (1985), Mn uptake increase when K is a low concentration in the growth medium but decreased its uptake when it was present in higher level concentration. These Authors have reported the beneficial effect of K on the uptake of Zn.

Attention to major nutrients management has been developed Myanmar, most farmers used to apply major nutrients N, P, and K as the form of straight or compound. But they hardly used other macros and micronutrients groups such as sulphur, zinc, and boron. An increased cropping intensity without matching increase amount in fertilizer inputs can cause depletion and imbalanced of both macronutrients and micronutrients (Ashamed and Eilas, 1986). The constant removal of crop residues from the field enhances the soil fertility decline. The worst practice is burning of residues resulting in nutrient losses from agricultural land up to 100% of N, 25% of P and K, and 60% of S (Fairhust, Witt, Buresh & Dobermann, 2005).

Although most of the farmers in Myanmar used to apply chemical fertilizers in rice production, balanced nutrition has been seldom achieved. Generally, farmers used N fertilizers with overdose (may be in somewhere) whereas they apply the insufficient amount in P and K resulting imbalance nutrient supply and low in productivity. On the other side, using the excess amount of fertilizer can cause nutrient leaching, eutrophication resulting in environmental pollution. The optimum productivity will be achieved when only by the supply of required nutrient with right time, a right source at the right place in the amount of right does that plant needs. Since some amount of nutrients are provided by soil indigenous, thus fertilizer recommendation rate for target yield can be efficiently and correctly done by knowing the indigenous nutrient level of soil with low and effective cost. The amount of indigenous nutrients supplied by a farmer’s field has been developing by omission technique in Site-Specific Nutrient Management approach (SSNM). It is developed in many countries throughout the world rice growing countries, including Asia, Southeast Asia, neighboring countries, and even in Myanmar (Htwe, 2015).

2.4 Significance of Micronutrients

The term micronutrient and trace element do not mean that the nutrients are somewhat less important than macronutrients. The importance of micronutrients has been realized in the world during the past four decades when wider spread micronutrient deficiencies were observed in most of the soil where intensive agriculture is practiced. The factors affecting micronutrient deficiency are: greater removal of micronutrient from the soil in the intensive production practices, use of micronutrient free fertilizers, increase knowledge of plant nutrition including micronutrient, less use of animal manure and crop residues and increase adaption of HYV which may have higher micronutrient demand for its potential yield (Mumtaz et al., 2013). A part from major nutrients, sulphur, zinc and boron are getting vital in rice cultivation.

2.4.1 Importance of sulfur in rice cultivation

2.4.1.1 The role of sulfur in plant

The importance of S in Agriculture is being increasingly emphasized, and Sulfur has been known as an essential element for plant growth and development and classified as secondary elements for plants. S functions in the plant are; helping to develop enzyme and vitamins, grain production, chlorophyll formation although it is not a constituent of chlorophyll. It is present in several organic compounds (International Soil fertility Manual, 1995). Sources of sulphur are Ammonium sulfate (21%S), Potassium sulfate (18%S), Magnesium sulfate (14%S), Elemental S (>85%) and Gypsum (18%S). Most of the fertilizer S sources are sulfate and moderately and highly water soluble. The most important water insoluble S fertilizer is Elemental S, which must be oxidized to the sulfate S form before the plant can use it.

Crops response to S and its deficiency has been noticed in a wide range of soil throughout the world. S deficiency in rice crop is also getting increasing as the use of S free fertilizers in a wide range. The main reasons of S deficiency in soil are (1) Low organic matter (2) Low mineralization rate of organic matter due to unfavorable environment condition (3) Depletion of soil indigenous S due to increased cropping intensity (4) Decreasing soil fertility level due to erosion (5) Applying high rate of major nutrients especially N and K (6) Use of S free fertilizers (7) Control of SO_2 emission in industrial areas (8) Low in parent material (9) Sandy leaching soil. It was reported by Arihara and

Srinivasan (2001). Deficiency of secondary elements including S is an important factor reducing macronutrient's efficiency especially in N and P and thus it is becoming crucial in cropping practices. Unlike the N, its symptom appears in younger leaves first because it is not readily translocated in the plants (International fertility manual, 1995). S is present in soil both inorganic and organic form, but the organic form is more prominent in agricultural soil (Yoshida, 1981). Organic form of S must be mineralized by soil organism before utilized by the plant. The oxidation of S in soil occurs through the chemical and biological process, especially by *Thiobacillus thiooxidans* (Fageria, 2009). It can move easily by soil water, and leaching may occur in sandy soil under high rainfall. S deficiency of low land rice has been reported by Aiyar since 1945 (Yoshida, 1981). The source of S was soil, rain and irrigation water and atmosphere (Yoshida, 1981). S use efficiency in field crops are 480 however, rice has much more than it possessing about 1307 SUE (kg grain produces with the uptake of 1 kg S in the grain (Fageria, 2009). S use efficiency is higher in cereals than legume and oil seed crops.

2.4.1.2 Function of sulphur in plant

Sulphur is an important component in two amino acid (Cysteine and Methionine) and play in important role in enzyme activation and decrease some fungal disease. Although it is not a constituent of chlorophyll, take in part in chlorophyll formation enhancing the early maturity of grain and improve quality in cereal crop at milling and baking (Fageria, 1989, as cited in Fageria, 2009).

Interaction of S and N is pervasive, and S requirement is resulting from increased N in the growth system. The need for S is closely related to the amount of N available to plant because they are constituents of proteins and associated with chlorophyll. The optimum ratio of N: S is 7:1. S can reduce soil pH and improve as consequent uptake of micronutrients such Fe, Mn and Zn and major nutrient P (Yoshida, 1981). Suzuki (1995) also pointed out that S deficiency can be induced by an excess amount of Zn in rice. Efficient fertilizer management such in N, P, K Ca, and Mg are required to maximize S use efficiency too, (Fageria, 2009).

2.4.1.3 Source of sulphur fertilizers

There are several sources of sulphur to correct the crop deficiency in Agriculture. Principal source of sulphur are described in Table (2.1). The dominant source of sulphur are single superphosphate, gypsum, and ammonium sulfate. Besides S, these sources can supply phosphorus, calcium and nitrogen, respectively, to plants. Sulphur can lost by leaching during crop season from soil based on rainfall intensity, timing of application and, SO_4 adsorption capacity.

The most common use sulphur source are sulphur coated urea, di-ammonium phosphate, mono-ammonium phosphate and triple superphosphate (Yasmin, Blair & Till. 2007). He applied the five source of sulphur tested for rice, i.e., elemental S, sulfur-coated urea, sulfur-coated di-ammonium phosphate, sulfur-coated triple superphosphate, and gypsum. The use of adequate rate of S is an important strategy to improve crop yields and maximize S use efficiency by crop plants.

The recovery efficiency of elemental S in rice is 46.7%, sulfur coated urea is 45.5, sulfur coated di ammonium phosphate, and gypsum is 38%, and S coated superphosphate is 32.3% enhancing the overall average is 40 in percent. Fageria (2009) stated that the S requirement varies from 10 to 60 S kg ha^{-1} depending on crop species, type of soil, and management practices. The sulphur requirement in cereal was low and as less than 20 kg ha^{-1}, (Fageria, 2009). However, Samosir and Blair (1983) applied 30 kg S ha^{-1} in his study on flooded rice at low fertility soil. The methods to against S deficiency are soil application of elemental S 20-40 kg ha^{-1}. S can be applied in a band or broadcast. S management practices are crop rotation, use of organic manure, methods of conservation tillage system, and improvement of water use efficiency. Maintenance of organic matter at an adequate level in the soil is the most efficient practices in prevention S deficiency in field crop since much of the S is held in the organic fraction of soil.

Although S deficiency is a common nutritional disorder in upland rice, its deficiency symptom of low land rice had also been found even in Myanmar since 1945 (Aiyar, 1945, as cited in Yoshida, 1981). Sulfate is reduced to sulfide in flooded condition; consequently, sulfate concentration decline rapidly, and thus, the availability of sulphur decreases as a soil reduction process (Yoshida, 1981). SO_4 reduction rate also depends on soil properties. The concentration of SO_4 at 1500 ppm in neutral soil to alkaline soil may be reduced zero within six weeks after submerged in rice land (Ponnamperuma, 1972).

Thus, sulphur may be deficient not only in upland but also in lowland rice soil, and S application in rice production is essential at last. The sulphur response on rice yield is seventeen (17%) percent in deficient soil (The sulphur institute, 2018).

Table 2.1 Source of sulphur fertilizers

Source	**Formula**	**S percent**
Ammonium sulfate	$(NH_4)_2\ SO_4$	24%
Ammonium polysulfide	NH_4S_x	45
Ammonium sulfate nitrate	$(NH4)_2$ SO4. $NH_4\ NO_3$	12
Ammonium thiosulfate solution	$(NH4)_2S_2O_3$+H_2O	26
Magnesium sulfate	$MgSO_4.2H_2O$	13
Gypsum by product	$CaSO_4.2H_2O$	17
Single superphosphate	$Ca(H_2PO_4)_2$+ $CaSO_4.2H_2O$	12
Triple superphosphate	$Ca(H_2PO_4)2.H_2O$	1.4
Copper sulfate	$CuSO_4.5H_2O$	13
Zinc sulfate	$ZnSO_4.H_2O$	18
Elemental sulfur	S	100
Sodium sulfate	$Na_2\ SO_4$	23
Potassium sulfate	K_2SO_4	18
Manganese Sulfate	$MnSO_4.4H_2O$	14.5
Iron sulfate	$FeSO_4.7H_2O$	11.5
Sulfur dioxide	SO_2	50
Sulfuric acid	H_2SO_4	32.7
Ferrous ammonium sulfate	$Fe(NH_4)_2SO_4$	16

Sources: Adapted from Fageria, 2009; Tisdale et al. 1985

2.4.2 Importance of Zn in rice cultivation

2.4.2.1 The role of Zinc in plant

Zinc is a micronutrient needed in a small amount for the plant, but its importance in crop production is not the least. It is found that the second most nutritional severe disorder is limiting in the yield of low land rice in Philippine by De Datta (1981) and in the US by Fageria et al., (2003). Graham, Welch, Grunes, Cary, and Norvell (1987) stated that 50 percent of cereal growing area are deficient level in Zn throughout of the world. Most of the scientists noticed that 30 percent of yield decreases in wheat, rice, corn, and other staple crops are resulting from Zn deficient soils even in moderate level. In highly weathered Oxisol and Ultisol, Zn deficiency can be found mainly since the low level of it's in the parent material (Landon, 1984).

Where soil in high pH, low organic matter, increased cropping intensity may be deficient in Zn (Landon, 1984). Yoshida (1981) reported that Zn deficiency could be seen widely in near neutral to alkaline soil, particularly in calcareous soil. It is associated with several unfavorable environmental conditions for uptake and utilization. Today, Zn deficiency widely spread throughout the world, especially in Asia (Asian Network for scientific information, 2001). In plant oxidation-reduction reaction in chlorophyll, formation is controlled by various enzymes in which Zn is the main constituent. Rice plant take up Zn every season, and 215g Zn is removed for 5 ton ha^{-1} yield (International soil fertility manual, 1995). The high concentration of Ca and P will inhibit Zn uptake from the soil. The ratio of P and Zn (P: Zn) in the soil is also important. It can be applied as a soil application, root dipping, and foliar. However, the best method for correcting Zn deficiency is broadcasting or beside the rows. (Fageria, 2009). Zinc ion in solution is very phytotoxic to green leaves and tissue, for the growing season, the Zinc application as chelated forms or fungicides containing zinc such as Ziram are the safest formulations to use (AGFIRST, 2018).

2.4.2.2 Function of Zinc in plants

Zn has many biochemical functions in the plant. It takes part in producing chlorophyll and forming carbohydrate and assist the plant growth substance and enzyme systems. It also involved in N metabolism, carbohydrate metabolism and starch formation of plant (Fageria, as cited in Fageria, 2009). It can improve root development, water use efficiency and disease resistance (*Rhizoctonia solani*). Zn contributes in chlorophyll formation and activates many enzymes, so Zn deficient symptom includes chlorosis and stunted growth (the-sulphur-institute, 2018).

Duffy (2007) stated that Zn is not very mobile in plants, so symptoms appear on the younger leaves and interveinal chlorosis can be seen under Zn deficiency in the plant. Mortvedt (1994) stated that recovery of the applied micronutrient is relatively low (5-10) while it is (10-50%) in macronutrient. Bishop (2013) also stated that uptake of metal micronutrient is lesser than that of non-meatal nutrients.

Acidic fertilizer such as ammonium sulfate, calcium sulfate increase Zn availability, whereas nitrochalk ($CaNO_3$), calcium carbonate ($CaCO_3$) reduces enhancing soil pH increases (Alloway, 2004). An excess amount of P can interfere with the metabolic function of Zn. Also, Mg, Cu, Fe, and B can decrease Zn availability (Brady & Weil, 2002). And also, Grunes, Alpaslan and Inal (1998) stated that Zn deficiency increases B uptake, and K increases Zn uptake.

Appropriate source, method, and rate of application are good management practices to improve Zn use efficiency. Water solubility level of Zn fertilizer exceeded 40-50% are needed to meet Zn requirement for the current crop. (Mortvedt, 1992). Zn use efficiency in grain was greater than pulses. Its recovery efficiency was found at 6 to 13 depending on applied rate and plant genotype (Fagenia, 2009). The critical level of Zn deficiency in the rice plant is about 15ppm. Zn content in the whole shoot Yoshida (1981) found was over 20 ppm.

2.4.2.3 Source of zinc fertilizers

There are various source of Zinc fertilizer which is described in Table (2.2). The most effective way to correct Zn deficiency was based on its water solubility (Gangloff, Mortvedt, Peterson & Westfall, 2000 and Mortvedt, 1992). The water solubility levels of about 40–50% of the total Zn in fertilizers are needed to meet the Zn requirements for the current crop (Amrani, Peterson &Westfall, 1999 and Mortvedt 1992), and high correlations have been found between Zn fertilizer’s water solubility and plant growth and Zn uptake (Amrani et al., 1999). The most common sources of zinc fertilizer was zinc sulfate and zinc oxide (Fageria, 2009).

Zn uptakes indicated difference in the performance of source; it does not effect on grain yield (Giordano & Mortvedt, 1972). Zn recovery efficiency by upland rice genotypes is scarce. It was reported by Mortvedt (1994) that crop recovery of applied micronutrients is relatively low (5 to 10%) compared to macronutrients (10 to 50%). Further, he stated that such weak recovery of applied micronutrients is due to their uneven distribution in soil because of low application rates, reaction with soil to form unavailable products, and low mobility in soil.

Table 2.2 Source of Zinc fertilizer

Source	**Formula**	**Zn percent**
Zinc sulphate(monohydrate)	Zn $SO_4.H_2O$	36%
Zinc sulfate (heptahydrate)	Zn $SO_4.7\ H_2O$	23
Zinc oxide	ZnO	78
Zn carbonate	$ZnCO_3$	52
Zinc sulfide	ZnS	67
Zinc phosphate	$Zn_3(PO_4)_2$	51
Zinc EDTA chelate	Na_2ZnEDTA	14
Zinc HEDTA chelate	NaZn HEDTA	9

Source -Foth and Ellis, 1988; Tisdale et al. 1985.

2.4.3 Importance of boron in rice cultivation

2.4.3.1 The role of boron in plant

Application of modern crop cultivar is highly sensitive to low micronutrient level, including B (White & Zasoski, 1999). Boron deficiency is widely associated with soil derived from strongly weathered grey rock. Parent rock and derived soil are the primary sources of soil B content. Sillanapaals (1999) observed that 30% of soil from 190 samples of 15 countries are low in B. Factor affecting in B availability are soil solution pH, texture, moisture, temperature, oxide content, carbonate content, organic matter content and type of clay. Fine texture soil is higher 2-3 times than coarse texture in B adsorption. Low organic matter, high rainfall, and sandy soil can reduce B availability with high leaching process. Phyllosilicate clay (muscovite, biotite illite, montmorillonite, kaolinite, and chlorite) also contain B and enhancing the activity of this element. Boron is very mobile in soil but in the plant, that its deficiency symptom appears first in the younger leave or growing point (Fageria & Baligar, 2005a). As a result of its effect on the development of meristem or actively growing tissue, the symptoms are the death of growing point in shoot and root (Fageria & Gheyi, 1999). For getting high yield of rice, B plays a vital role because it induces grain sterility when it is deficient. 60 g B will be removed from the soil for 5 ton ha^{-1} yield. Where the soil has high clay content, high organic matter, and derived from highly weathered acid soil, it may be more deficient (Landon, 1984). B deficiencies are a wider spread in any part of the world. Crops vary widely in their needs for and tolerant to B, yet, the line between deficient and toxic amount is narrower than any other essential nutrients. Jone (1991) reported that B sufficiency range is 20 to 100 mg kg^{-1} in fully matured leaves.

It can be applied as a broadcast or band application, or foliar. Soil application rates for responsive crops are as high as 3 kg ha^{-1} while low and medium responsive crop 0.5 to 1.0 kg ha^{-1} (International soil fertility manual, 1995). It has been cleared that these two micronutrients (Zn and B) become prominent in rice cultivation (Mookherjee, & Mitra, 2016). Shorrocks (1997) recorded that a total of about 15 million hectares of agricultural land are applied B fertilizer annually.

2.4.3.2 Function of boron in plant

Primary cell-wall structure and membrane function are closely linked to boron nutrition; however, due to the lack of suitable information, B function in metabolic events has never been adequately evaluated. But the role of B in the physiology of plants are cell-wall structure, and pollen tube growth and pollen germination (Mumtaz et al., 2013). It is cleared by Tanada (1983) that boron plays an essential role in nutrient transport by plant membrane. It may have a function of regulator or inhibitor in the accumulation and utilization of other nutrients. It has been found that the increase of B uptake decreases cation-anion equivalent ratio in the leave and increase in the roots of the alfalfa plant, (Wallace & Bear, 1949). Santra, Das and Mandal (1989) reported that B has not the only effect in the plant but also the nutrient medium and thus, B influence nutrient availability from the soil. Rice plant recorded the highest yield and yield component like productive tillers, panicle length, and grain weight with boron fertilization (Sarwar, Ali, Irfan, Akhter & Ali (2016). Dash, Sign, Mahkud, Pradhan and Jena (2015) also stated that boron is very much essential for flowering and grain formation in rice and having a significant effect on major nutrient (NPK) uptake. B involve in carbohydrate transport in plants: assist in metabolic regulation (The sulphur-institute, 2018). Tariq and Mott (2007) reported that B increased N uptake and favorable for nodule formation.

There is a positive relationship between boron and K and N for crop yield, however high B induce low uptake of Zn, Fe, and Mn. B accumulation is enhanced by Zn deficiency. Thus, its toxicity can be corrected by Zn application (Graham et al., 1987).

Adopting appropriate soil and crop management practices can improve uptake and efficiency of B fertilizer. Boron fertilizer can be applied as broadcast, band, or foliar. However, soil application is more effective than foliar application in the annual crop. However, boron recovery under field conditions by annual crops is generally in the range of 5 to 15% (Shorrocks, 1997). Eraslan, Gunes, and Alpaslan (2007) stated that optimum level of B is very low hence it is need to take of B fertilizer application. Cox (1987) reported that the critical level of B is 0.1 to 2 mg kg^{-1} in the soil. Toxicity of B can be managed by applying high organic matter level (London, 1984).

2.4.3.3 Source of boron fertilizers

In boron deficient soils, application of appropriate source is important to improve crop yield and fertilizer use efficiency. The principal B source was described in Table (2.3). The most common use of B fertilizer are boric acid, borax or sodium tetra borate. The source of B and its boron content expressed in Table (2.3).

Table 2.3 Source of boron fertilizer

Source	**Formula**	**B percent**
Boric acid	H_3BO_3	17
Borax	$Na_2B_4O_7.10H_2O$	11
Sodium borate (anhydrous)	$Na_2B_4O_7$	20
Sodium pentaborate	$Na_2B_{10}O_{16}10H_2O$	18
Sodium tetraborate pentahydrate	$Na_2B_4O_{7.}5H_2O$	14
Boron oxide	B_2O_3	31

Source: Fageria (2009)

2.5 Nutrient Uptake and Their Effect

Nutrient use efficiency of micronutrient has been found by Shahzadam (2006). Accordance with his study although the macronutrient efficiencies were 30-50 in N, 15-20 in P, 70-80 in K and 8-10 in S, micronutrient efficiency was observed just about 1-2 (Shahzadam, 2006). Dash, Singh, Mahakud, Pradhan and Jena (2015) have found that macronutrient accumulation was increased by sulphur, zinc, and boron. Similarly, less of sulphur accumulation can be seen in N omission and decreasing the yield in 37 percent. Combined application of N, P, K and S, Zn, B result in significantly higher Zn and B content in the plant. According to Dash et al (2015), uptake of S in grain was 6 kg ha^{-1} and 14 kg for rice yield of 7.84 ton ha^{-1}. Total uptake of B in upland rice was 82.57 g ha^{-1}. Zn use efficiency in grain was greater than pulses. Its recovery efficiency was found at 6 to 13 depending on applied rate and plant genotype (Fageria, 2009). Among the micronutrients, uptake of non-metal micronutrients are considerable higher than that of metals (Bishop & Manning, 2013). The highest uptake of N, P, K, S, Zn, B with combined micronutrient treatments was found by Baktear, Kumar & Ahmed (2001). The preliminary results suggested that application of micronutrients along with NPK, is necessary for obtaining a satisfactory yield of rice (Baktear et al., 2001).

2.6 Sustainable Agriculture with Balanced Plant Nutrition

While Myanmar is trying to attempt the development of sustainability in the Agricultural sector, increasing crop productivity and maintaining natural resources is equally important. To meet this aim, balanced fertilization not only in macro but also in micronutrients is essential, especially in rice production. With proper management of soil and nutrients, productivity will be increased sustainably conserving the natural resources without adverse environmental effects.

Pattanayak et al. (2008) pointed out that inadequate and unbalanced nutrient use is one of the major factor responsible for low productivity. Balanced nutrient management offers an opportunity to not only crop productivity but also provide an option for rebuilding soil organic matter (Rusinamhodzi et al., 2014). According to Liebig’s law (1873), plant growth is regulated by the factor present in the minimum amount, and the yield will be determined by the level of that factor. While plants take up all essential elements, the application of just three major elements is not enough for long term sustainability and enhances the multi-nutrients deficiency in rice. Today, secondary (macro) and tertiary (micro) nutrients such as sulphur, zinc, and boron become a crucial role in rice cultivation. Because of increased cropping intensity in rice field, especially irrigated land, these elements deficiency become severe problem day by day. Mookherjee and Biplab (2016) stated that aside from NPK, Sulphur, Zinc, and Boron play an important role in the agricultural crop production system.

Balanced plant nutrition means an approaching at not only majornutrients NPK but also secondary nutrients and micronutrients. While world population is increasing day by day and it will be 9.8 billion in 2050 and about 30% may be higher than that of today, increasing food demand with limited land, limited water resource is challenges of future agriculture. Limited resources and less damage to forest and little or no damage to the environment is the expected picture of future agriculture. Therefore, while we have to try sustainability in the agricultural sector, we have to shift from resource-based agriculture to science-based agriculture. Among two option that we have to improve crop productivity since horizontal expansion is almost saturated, the possible way to meet our goal is a vertical improvement (increase yield). The potential yield of the crop cannot be obtained without adding required nutrients, and thus, nutrient management becomes a crucial role in this sector. While plants take up all essential elements, the application of just three major elements is not enough for long term sustainability and enhances the multi-nutrients deficiency in growing crops. The Law of minimum developed by Justus Von Liebig also stated the nutrient that is available to plant in the least or limiting amounts of elements is what will lead to determining the yield of the crop even if other nutrients are available in optimal amount.

Most of the farmers want to produce maximum product form their land as intensive cultivation with early variety. High yielding but without paying much attention to soil nutrients and soil health that results in a decrease in yield and quality, the effect on consumer malnutrition and environmental concern, especially in fertility depletion. The highest significant yield was recorded when the crop received all the nutrients (NPKSZn and B). Decreasing of yield in the absence of S, Zn, and B at 8 percent were observed by Dash et al., (2015).

The yield of rice has stagnated or on the decline as the micronutrients has emerged as a yield-limiting factor in soils. Soil deficient in micronutrient is not capable of healthy crop plant successfully, and therefore, low yield and poor quality of crops are obtained. Among the micronutrients, zinc and boron play an important role in grain setting and yield of crops. Among the minor nutrients, B greatly affects the N, P, and K uptake as compared to S and Zn (Dash, et al., 2015). The highest grain yield of 4850 kg ha^{-1} was obtained when S, Zn, and B were applied together with NPK fertilizers. It was found that the application of S, Zn, and B along with NPK, gave a maximum yield of BRRI Dhan-30 by Uddin, et al., (2002). Besides, the combined application of S and B significantly increased the number of effective tillers, panicle length, and grain yield of rice (Afroz, Zaman, Halim Razzaque & Zamil, 2015). However, the excess amount of some nutrient such Ca inhibit the plant growth and other nutrient availability such as boron, iron, manganese, copper, or zinc.

Nutrient balancing between micronutrient is important but more than difficult to manage that between of macronutrients. The optimum quantity of nutrients may have synergism to other nutrients while the excess amount may have antagonism effect on others. Shara (2017) reported that the excess amount of N reduce the uptake of P, K and almost all secondary and micronutrients. Additionally, the antagonistic effect of K and Mg and Ca is also pointed out by Johnson et al (1968). The reducing of uptake in B by K was found by Hill and Morririll (1975) and Gupta (1979). Synergism effect of micro nutrients have been found by many scientist in their study.

The improved Mo uptake by acid forming N fertilizer, increase P uptake by Mg and increase uptake of Mo by P fertilization were recorded by department of nutrition and program of international nutrition university, USA. Furthermore, the synergistic effect of nitrogen and sulphur were observed by Saha and Detta (1991). The synergism is the positive effect of adding nutrients. It means the application of one nutrient increase the availability of other nutrient. The positive and negative effect of nutrients can be seen in Table (2.4) and (2.5). Sulphur has interaction both synergies and antagonist with other elements, especially Nitrogen. The combined effect of S and N on yield and recovery by the crop is more significant than that by alone. The synergetic effect on the groundnut is 22% in kernel and 43 % in oil yield by sulphur and boron (sulphur-institute, 2018).

Zn application improved uptake of N, Mg, and Cu in the bean. But the high level of Mn in combination with high iron (Fe) can reduce Zn uptake in flooded soil resulting in Zn deficiency. An excess amount of P can interfere with the metabolic function of Zn. Also, Mg, Cu, Fe, and B can decrease Zn availability (Brady &Weil, 2002). And also, Grunes, Alpaslan, and Inal (1998) stated that Zn deficiency increases B uptake, and K increases Zn uptake.

Tariq and Mott (2007) studied the positive effect of boron on phosphorus and potassium uptake resulting from alerted the permeability of plasma lemma at the root surface. Pollard, Parr, and Loughman (1997) also found that B deficiency in corn and broad bean reduced the capacity for the absorption of P, due to reduced ATPase activity, which could be rapidly restored by the addition of B. Interaction effect of nitrogen, phosphorus, and potassium with sulphur, boron and zinc on yield and nutrient uptake by rice under Rice-Rice cropping system in inceptisol of coastal Odisha was observed by Dash et al., (2015).

Table 2.4 Synergic effect of nutrients

The optimum quantity of nutrient	Positive effect on another nutrient
Nitrogen	Uptake of P, K, Fe, Mn, Cu, Ca
Cu and Boron	Improve uptake of N from soil
Mo	Improve utilization of N
Ca, Zn, Cu, Mo	Increase uptake of P, K
S	Increase uptake of Mn, Zn
Mn	Increase uptake of Cu

Source: Fageria (2009)

Table 2.5 Antagonist effect of nutrients

Excess quantity of nutrient	Negative effect on other nutrients
Nitrogen	Decrease uptake of P, K, Fe, Mn, Zn, Cu, Ca, Mg
Mg and Fe	Reduce uptake of P from soil
P	Reduce uptake of Cu, Fe, Mn, Zn
K	Reduce uptake of Ca and Mg
Zn	Reduce uptake of P, Fe, Mn, Cu, Mo
Ca	Reduce uptake of Fe
Fe	Reduce uptake of Zn
Mn	Reduce uptake of Zn

Source: Fageria (2009); Shara Ross (2017)

CHAPTER III
MATERIALS AND METHODS

To evaluate the balanced macronutrient and micronutrient fertilizer application in rice cultivation, the study was carried out with three main objectives in 2017 and 2018. They are determination of soil fertility status, pot and field experiments.

3.1 Study Area and Experimental Site

There are 67.67 M ha total cultivable land in Myanmar. Among them 25% of cultivable land are the rice growing area accounting 17.8 M ha. Twenty four major soil types are classified in Myanmar and three out of them are rice soils namely Fluvisol, Gleysol and Vertisol. The Greysol is the largest portion and possessing 90 percent of rice land in Myanmar. There are many sub soil type under it and where there are in upper Myanmar is neutral to alkaline condition whereas in lower Myanmar and hilly region are in slightly acid condition. Rice growing area of Naypyitaw is Greysol which is mainly focused in this study. Therefore, the collection of soil samples and survey study was done in Pobbathiri and Zeyarthiri township of Naypyitaw council area where is situated between 19˚24' -20˚18' N and 95˚40' - 96˚40' E at 410 ft above sea level. Two field experiments were conducted in farmer's field, one in Pobbathiri and another in Zeyarthiri Township during rainy (wet) season of 2017. Pot experiments were conducted at Department of soil and water science, Yezin Agricultural University which is situated at 19˚38'N latitude and 96˚50' E east Longitude and 102˚ N Latitude during summer season (dry) season of 2017 and rainy season (wet season) of 2018.

3.2 Determination of Soil Fertility Status

In this study the collected data were based on primary and secondary data source. As the secondary data, the general condition of Naypyitaw union territory and collected a total of 240 composite soil samples from two districts, 8 townships which consists 169 soil sample from rice growing area were recorded to evaluate the fertility of the study area. Soils were analyzed for the soil pH, organic carbon, total Nitrogen, available Phosphorus and available Potassium. Soil sample taken from respective townships were described in Table (3.1).

Table 3.1 Number of soil sample taken for study on fertility status in Naypyitaw region

District	Township	No. of soil sample from Agricultural land	No. of sample from Rice field
Dakhina District	Pyinmana	26	18
	Lewe	48	35
	Zabuthiri	4	4
	Dakhina	10	10
	Total in Dakhina	88	67
Ottrathiri District	Tatkone	72	43
	Zeyarthiri	26	22
	Pobbathiri	33	23
	Ottrathiri	20	14
	Total in Ottrathiri	151	102
Naypyitaw	Total	239	169

As the primary data source soils were collected from rice field of Set Set Yo farm (Pobbathiri township) and Thitat village tract (Zeyarthiri township) which are major rice growing area of Ottrathiri district. To evaluate the fertility status of rice land in study area, a total of 22 composite soil samples were collected from rice growing fields which consisted of 12 fields from Pobbathiri and 10 fields from Zeyarthiri Township. The collected soil samples were sent to Land Use Division Lab, Department of Agriculture in Yangon for analyzing soil fertility status. Soil physicochemical properties were analyzed and recorded as soil texture, organic carbon, total nitrogen, available phosphorus, exchangeable potassium and sulphur, zinc and boron in laboratory.

At the same time, farmers owner of the sample rice fields were interviewed with structure of questionnaire (Appendix-1) to access socio economic factor, cropping pattern, cropping intensity and cultural practices concerning about the opinion on the fertilizer management. Data were analyzed using chi square test to study dependency of nutrient level based on location and cropping pattern.

Following formulas were used to analyze the survey and soil test result.

$$x^2 = \sum_{i=1}^{p} \frac{(ni-Ei)^2}{Ei}$$

P = number of class

ni = Observed no of the unit in class i

Ei = Expected no of the unit in class i

3.3 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application (Pot Experiment)

The first pot experiment was carried out during summer (dry) season of 2017. The experiment was started from April and ended at August 2017. The 2×8×3 factorial arrangement in randomized complete block design was used. The variety used in experiment was Yadanatoe (120-130 days maturity). There were two different soils such as Pobbathiri and Zeyarthiri soil. Experimental soils were collected from farmer’s field from Pobbathiri and YAU field from Zeyarthiri Township. The different fertilizer combinations were used as another factor. Basic applied fertilizer were urea, triple super phosphate and muriate of potash and used additional approach with secondary (S) and micronutrients (Zn and B).

The fertilizer combinations used in this study were as followed.

T_1 - NPK,

T_2 - NPK+ S,

T_3 - NPK+Zn,

T_4 - NPK+B,

T_5 - NPK+S+Zn,

T_6 - NPK+S+B,

T_7 - NPK+Zn+B and

T_8 - NPK+S+Zn+B.

All pot received NPK fertilizer at the blanket rate of 85 kg N, 13 kg P and 30 kg K per hectare as urea, triple super phosphate (TSP) and muriate of potash (MOP). The rates of 30 kg S ha^{-1}, 5 kg Zn ha $^{-1}$ and 3 kg B ha^{-1} were applied as sulphur, zinc oxide and boric acid, respectively. The entire amount of TSP, sulphur (100% S), zinc oxide (78% Zn) and boric acid (17% B) were applied as basal application. In case of urea and MOP, two equal split applications were done at (14 DAP) and maximum tillering stage (42 DAP).

The size of pot used in this experiment was 30 cm diameter and 30 cm in height. Each pot was filled with tested soil at the rate of 15 kg. All pots were filled with water and maintained water level 5 cm above soil surface. The 20 days old seedling were transplanted on 23rd April, 2017. Weeding was done manually 14 and 42 day after transplanting. (DAP). To protect the pest problem, 3 gm carbo-furan insecticide was applied at the rate of 12.5 kg ha^{-1} at basal. All pots were harvested at 105 DAP on 7th August, 2017. The second pot experiment was conducted during rainy (wet) season of 2018. The experiment was started September and harvested in January, 2019. Soils were taken from rice field of Pobbathiri Township.

The use of experimental design was simple RCB design and fertilizer combination, cultivar were the same as mentioned in the first pot experiment. All the treatment application and crop management were done same procedure in the first pot experiment. All pots were harvested in 1st week of January, 2019.

3.4 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application (Field Experiments)

Two field experiment were conducted in farmer's field of Pobbathiri and Zeyarthiri Township during rainy (wet) season, 2017. The experiment was laid out Randomize Complete Block design having eight treatments with three replications in each location. Individual plot size was 5 m × 5 m and the eight combination of different fertilizer application were used as mentioned in Section 3.3.

Experiments were grown on last week of July and harvested on 7th and 9th December, 2017. Twenty days old seedling were transplanted at a 20 cm × 20 cm spacing. Plots were irrigated starting two weeks after transplanting and continued to maintain soil submergence until the heading stage. Water was drained two weeks before harvest. Hand weeding was done at 14 and 42 DAP. Pest and disease control followed standard practices by department of agriculture and no damage occurred during crop season. Experimental plots were harvested on 9th December, 2017 in Pobbathiri and on 7th December, 2017 in Zeyarthiri.

3.5 Soil Sampling and Analyzing

The representative soil samples (0-15 cm depth) were collected for chemical analyses. For the initial soil test, a composite soil sample was taken from respective field for pot experiments. In field experiments, randomly-collected 20 samples were taken from experimental sites. And then soils were thoroughly mixed, air dried and ground to pass through 2 mm sieves. The soil sample were analyzed for organic carbon, texture, soil pH, and nutrient status of total and available N, available P, available and exchangeable K, Ca, Mg, available S, Zn and B.

Soil pH was measured using a pH meter (1:2.5 soil: water). Available N and total N % were determined by Kjeldahl extraction, digestion, distillation, and titration method (FAO, 2008). Available P were analyzed by Bray's extractant (Bray & Kurtz, 1945) and available K was determined by direct Flame photometry method. Secondary element Ca and Mg were analyzed by EDTA method. Organic carbon was determined by dichromate oxidation (Walkley & Black, 1934), soil texture (Pipette method) and available S, was determined by titration with EDTA method, available Zn was determined by ammonium acetate methods and measured by Atomic Absorption Spectrophotometer, and B was determined by hot water extractable method.

3.6 Plant Growth Characters, Yield and Yield Components

Plant height in every experiment and number of tiller hill^{-1} were recorded two-week interval. The panicle length were recorded at harvest time. Plant height, tillers number and panicle number per hill were recorded from 16 hills adjacent to the harvest area in field experiments.

The yield was recorded in harvest area of experiment plot, and contributing data were determined from every 12 plants at the sampling area of the plot. The contributing data for yield were number of productive tillers hill $^{-1}$, number of spikelet panicle $^{-1}$, filled grains percent, thousand grain weight (g). Grain yield was determined as plot yield and then calculate as a t ha^{-1}. In the pot, experiments yield and yield contributing data were recorded and then calculated as yield t ha^{-1}.

3.7 Plant Sampling and Analysis

In second pot experiment, not only the yield and yield contribute data but also nutrient uptake of plant sample were analyzed and recorded for detail study. To analyze the plant sample, grain and straw samples were taken separately then finely ground (0.5 mm) and the nutrients (N, P, K, S, Zn and B) content in grain and straw were determined by distillation analysis. Plant analysis were done at land use division, Department of Agriculture in 2019.Nutrient up takes calculated by using the following formula. (Dobermann and Fairhurst, 2000).

$$\text{Nutrient uptake (kg ha}^{-1}) = (GY_3 \times N_{GO})/100 + (SY_3 \times N_{St})/100$$

Where, GY_3 = oven dry grain (kg ha^{-1}),

SY_3 = oven dry straw (kg ha^{-1}),

N_{GO} = nutrient concentration in grain (%), and

N_{St} = nutrient concentration in straw (%).

Oven dry grain yield was estimated by using guide line of Dobermann and Fairhurst (2000).

$$\text{Oven dry grain yield (GY) = Grain yield at 14\% moisture (GY 14\%)} \times 86/97$$

Fertilizer Use Efficiency was calculated as Agronomic Efficiency (AE), Partial Factor Productivity (PFP) and Nutrient Harvest Index (NHI) by using the following formulas (Win, 2003).

Fertilizer use efficiency (Agronomic Efficiency) was calculated as

$$A.E = \frac{\text{Grain Yield in fertilized plot-Grain Yield in omission plot (kg ha}^{-1}\text{)}}{\text{Applied fertilizer (kg ha}^{-1}\text{)}}$$

(Novoa and Loomis, 1981)

Partial factor productivity (PFP) was calculated as

$$PFP = \frac{\text{Grain Yield (kg ha}^{-1}\text{)}}{\text{Applied fertilizer (kg ha}^{-1}\text{)}}$$

(Peng et al., 1996)

Nitrogen Harvest Index (NHI) was calculated as

$$NHI = \frac{\text{N accumulation in grain (kg ha}^{-1}\text{)}}{\text{Total N uptake (kg ha}^{-1}\text{)}}$$

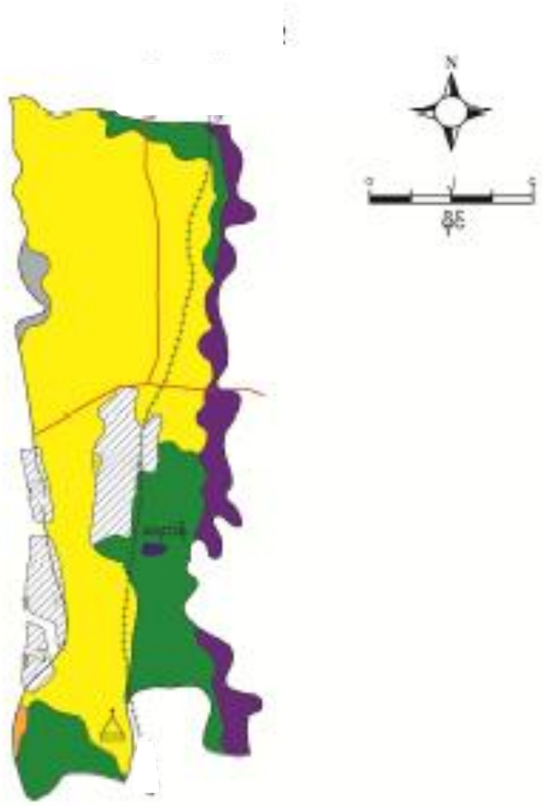
(Witt et al., 1999)

Similarly harvest index for other nutrients were also recorded; e.g. Phosphorus Harvest Index (PHI), Potassium Harvest Index (KHI), Sulphur Harvest Index (SHI), Zinc Harvest Index (Zn HI) and Boron Harvest Index (BHI) using this formula and calculated as percent respectively.

Due to the limitation of Lab facility in material and skilled person for plant analyzing in micronutrients at that time the research aim for only yield and yield contributing data and Fertilizer Efficiency (Agronomic Efficiency and Partial Factor Productivity) to be studied. However, plant analysis of last pot experiment was initiated in Land Use lab in 2019 to confirm the tested nutrient’s efficiency.

3.8 Data Analysis

Data were analyzed by STATISTIX version (8.0), and treatment means were compared with least significant difference (LSD) at 5 % level.



Meadow alluvial soil

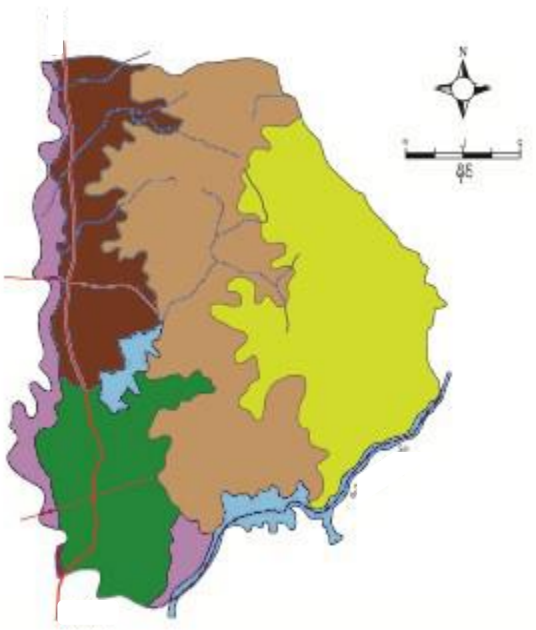
Red-brown forest soil

Yellow-brown gley soil

Yellow-brown forest soil

other soil

Plate 1 Soil Map of Pobbathiri Township



Meadow alluvial soil

Yellow-brown dry forest soil

Yellow-brown gley soil

Yellow-brown forest soil

Mountainous brown forest soil

Plate 2 Soil Map of Zeyarthiri Township

CHAPTER IV
RESULTS AND DISCUSSION

4.1 Determination of Soil Fertility Status

4.1.1 General description of study area

The study was carried out in Pobbathiri and Zeyarthiri township of Naypyitaw area which is new capital city of Myanmar and located in the middle part of Myanmar. General description of study area was recorded from Department of Agriculture (DOA) and Land Use Division report, (DOA) as secondary source. There were 8 town ships namely Tatkone, Lewe, Pyinmana, Zeyarthiri, Pobbathiri, Dakhinathiri, Zabuthiri and Ottrathiri widing 2748.61 sq. mile. It has a total population of 1.16 million with farmer house hold of 68484.The total land area is (706009.72 ha) and net sowing area is about (135978 ha).

Study area are major rice growing area of Ottrathiri district, Naypyitaw region possessing five major soil type; Meadow alluvial soil, Yellow brown dry forest soil, Yellow brown gley soil Yellow brown forest and Mountainous brown forest soil. Major crops grown in this area are rice, sugarcane and, pulses. As the secondary source based on 240 soil sample tests of Naypyitaw region, about 50% of Naypyitaw Agricultural lands were low in organic carbon (O.C). In major nutrients, 82% and 90% of the land were also deficient in total N and available P respectively. It contained only K in a substantial amount. Mostly the rice land is low pH, however, micronutrient deficiency may occur since it is adopted in high cropping intensity. Moreover, the yield level of rice is high and, the use of macronutrient (NPK) is also large in this area. It may induce other macronutrient and micronutrient deficiency in rice land. Most of the land are grown rice and cropping intensity of this area is above 150% having 176.51% in Ottrathiri district and 169.34% in Dakhinathiri. The cropping intensity of these area was described in Table (4.1). Some rice land area has high cropping intensity (C.I) up to (300) since they cultivated triple cropping system where the water is available. Most of the farmers in the study area depend on rice growing with high C.I and used improved varieties including hybrid rice and corn which are those heavy eater crop in nutrient point of view. Even then, the farmers didn't apply sufficient amount of nutrients on rice land let alone in upland crop resulting in nutrient depletion in soil. Although farmers apply fertilizer in substantial amount in the rice field, it doesn't cope with the removal of nutrient by growing crops especially in minor nutrients enhancing nutrient deficiency.

Table 4.1 Cropping Intensity (C.I) of Naypyitaw region

Township	Cropland (ha)	1st crop	2nd crop	3rd crop	Total	C.I (%)
Tatkone	43272.4	43272.4	38583.6	776.4	82632.4	190.96
Zeyarthiri	9292.4	9292.4	6809.2	195.6	16297.2	175.38
Pobbathiri	10055.6	10055.6	5278.0	69.20	15402.8	153.18
Ottrathiri	8738.8	8738.8	2860.8	21.60	11621.2	132.98
Ottrathiri District	71359.2	71359.2	53531.6	1062.8	125953.6	176.51
Pyinmana	13088.8	13088.8	8060	2827.2	239616.0	183.18
Lewe	46323.2	46323.2	28514.8	2690.4	77528.4	167.36
Zabuthiri	592.8	592.8	558.8	21.60	1173.2	197.91
Dakhinathiri	4614.8	4614.8	1940.0	192.00	6750.0	146.27
Dakhina District	64619.6	64619.6	39076.8	5752.8	109427.6	169.34
Total	135978.8	135978.8	92608.4	6794.0	235381.2	173.10

Source: Department of Agriculture (2016)

4.1.2 Fertility status of study areas

In the study of focus area Pobbathiri and Zeyarthiri, soil sample testing and farmer interview were used together. To evaluate the fertility status of study area, a total of 22 composite soil samples were collected from major rice growing fields of these townships and owner farmers of these field were interviewed for their copping practices.

According to laboratory test of taken soil samples, thirty percent were low in organic carbon, whereas available K were medium to a high level in all soil sample. Total nitrogen, sulphur, and zinc were low levels in all soil samples. Eighty-two percent of soil and 36 percent were deficient in available phosphorus and boron, respectively

According to a survey study, all farmers were lack of knowledge in soil and fertilizer practices. They never noticed nutrient removal and recommended fertilizer rate for their crops. They didn't know the nutrient requirements of their crop to obtain their targeted yield as the variety that they used. Generally, they apply a substantial amount of fertilizers in rice field but pulses. Their fertilizer rates were also determined by their common knowledge and their economy not based on nutrient uptake of their crops. The utilization of organic matter has never been met the needs of the plant's nutrients. Among the respondents, there were only two farmers, merely 10 percent who adopted rice after rice pattern since irrigation water was available in the summer season, but it was limited in later years. Most of the farmers (59%) adopted rice-pulse double cropping system, and the triple cropping system rice- pulse- rice were adopted at 32 in percent. Chi-square test was used to analyze the survey and soil test data based on location and cropping pattern, which were farmers adopted. The results were shown in Table (4.2) and (4.3).

Total nitrogen, available S, and Zn were deficient in all soil samples. Deficiency of organic carbon was significantly different in two locations at 0.05% level. Available phosphorus were found in low level but not significantly different in two locations. Available B was found in medium level in all soil of Zeyarthiri and about 30% of Pobbathiri rice land. Therefore, it can be said that boron deficiency was depending on regions. Its difference was significant at the 0.01 level. This study recorded that fertility status of rice land of Naypyitaw depending on sites. It was shown in Table (4. 2).

Table 4.2 Fertility level based on location

Particular	No. of soil sample Pobbathiri		No. of soil sample Zeyarthiri		χ^2 test
	Medium	Low	Medium	Low	
Organic Carbon%	6(8.18)	6(3.82)	9(6.82)	1(3.18)	*
Total N	-	12(12)	-	10(10)	ns
Avail P	2(2.18)	10(9.82)	2(1.81)	8(8.18)	ns
Avail K	12 (12)	-	10 (10)	-	ns
Avail S	-	12(12)	-	10(10)	ns
Avail Zn	-	12(12)	-	10(10)	ns
Avail B	4(7.64)	8(4.36)	10(6.36)	0(3.64)	**

Figures in the parentheses are expected value.

ns = non-significant,* = significant , ** = highly significant

Table 4.3 Fertility level based on cropping pattern

Particular	No. of soil sample						χ^2 test
	Rice- Pulses system		Rice- Rice system		Rice- Pulses- Rice		
	M	L	M	L	M	L	
Organic Carbon%	9(8.86)	4(4.14)	1(1.36)	1(0.64)	5(4.77)	2(2.23)	ns
Total N	_	13(13)	_	2(2)	_	7(7)	ns
Avail P	3(2.36)	10(10.64)	0 (0.36)	2(1.64)	1(1.27)	6(5.73)	ns
Avail K	13(13)	_	2(2)	_	7(7)	_	ns
Avail S	_	13(13)	_	2(2)	_	7(7)	ns
Avail Zn	_	13(13)	_	2(2)	_	7(7)	ns
Avail B	8(8.27)	5(4.73)	1(1.27)	1(0.73)	5(4.45)	2(2.55)	ns

Figures in the parentheses are expected value.

ns = non-significant,* = significant , ** = highly significant

Available K was not found in deficient level at all soil samples from all cropping system and available sulphur and zinc were found at a low level in every sample (Table 4.3). The fertility level of organic carbon, available phosphorus, and boron were different based on cropping pattern but not significant. However, the level of organic carbon in pulses growing area is higher than that of monoculture (rice after rice) system. Organic carbon level is low at twenty-eight to thirty percent of land in rice, pulses cropping pattern while fifty percent of land in rice after rice system was at the low level.

In the study of rice field in the study area, total N, available P, S, and Zn were deficient in all fields. Rice field in Zeyarthiri had more organic carbon and boron if it is compared to that of Pobbathiri. Some nutrient depletions were found significantly differences in two locations but not depend on cropping pattern. Deficiency of nutrient in the study area did not depend on grown crops conclusively. It might be due to the insufficient application of nutrients amount, type, and ratio. In this study, it could be found that all rice lands were deficient in sulphur and zinc and about 30 percent of it was low level in boron content.

This study demonstrated that, farmers did not aware to apply sufficient organic and inorganic fertilizers, and the results of the present study pointed out that the effective education system was required necessarily to encourage for adoption of the advanced fertilizer technology regarding balanced fertilization of macro and micronutrient.

The result from survey and soil lab test indicated that the study on “evaluation of balanced macronutrient and micronutrient fertilizer application in rice cultivation” was necessary for sustainable development of agriculture, especially in the rice sector. Major causes of fertility level might be due to the reflection of high cropping intensity and insufficient application of fertilizer to the soil. After knowing the fertility status and causes of these nutrient’s deficiency in rice land, two types of experiments were conducted in pot experiment and field experiment on farmer’s field to evaluate the effect of macronutrient and micronutrient on rice cultivation in study area.

4.2 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation (Pot experiment in dry season, 2017)

4.2.1 Physicochemical properties of experimental soil

In this pot experiment, soils were taken from two locations; one was farmer’s soil from Pobbathiri Township, and then rest one was YAU soil from Zeyarthiri Township. Their soil physicochemical properties were described in Table (4.4). According to study result, the soil from Pobbathiri soil was more abundant in organic carbon %, total N, available K, and Ca than Zeyarthiri soil while available P and Zn were found more in Zeyarthiri soil. Both of them were slightly acid condition and medium texture soil.

4.2.2 Plant growth in pot experiment

As the result of experiment, the plant growth characters were not significantly different with treatments. The plant height was collected in two-week interval started from 14 days after transplanting. Figure (4.1) and (4.2) showed the plant height with treatments, however, there were no significant differences. Number of total tillers hill^{-1} is significantly different between the soils but not found differences among treatments. Tillering capacity is higher in Pobbathiri soil than Zeyarthiri soil in every treatment. There were not significantly differences in panicle length among the treatments and between the soils (Table 4.5). Total dry matter (t ha^{-1}) was described in Table (4.5). Although the tillers were less in Zeyarthiri soil, Total Dry Matter (TDM) weight were higher than Pobbathiri soil. It may be result of greater the vigorous, and weight of tiller in pots of Zeyarthiri soil.

4.2.3 Yield and yield component in pot experiment (dry season, 2017)

According to the experimental result, filled grain %, and yield were significantly different among treatments. The result showed the number of tillers hill^{-1}, number of spikelets panicle^{-1}, filled grain %, yield and total dry matter were significantly different in soil based on locations. The length of panicle and thousand grain weight were not significantly different among the treatments and between the soils (Table 4.6).

4.2.3.1 Number of effective tillers hill^{-1}

The number of tillers hill^{-1} is greater in the Pobbathiri soil, but spikelets panicle^{-1} is greater in Zeyarthiri soil (Table 4.6). It showed that Pobbathiri soil can produce higher number of tillers since it has slightly increased total nitrogen and organic carbon. And due to the higher content of P and Zn, Zeyarthiri soil gave higher spikelets panicle^{-1} than that of Pobbathiri soil.

4.2.3.2 Number of spikelets panicle^{-1}

Adding fertilizer did not give significant differences in number of spikelets panicle^{-1} but there were significant differences between soils. The soil from Zeyarthiri gave the higher number of spikelets panicle^{-1} than that of Pobbathiri soil (Table 4.6).

Table 4.4 Physicochemical properties of experimental soils in pot experiment (dry season, 2017)

Particular	Pobbathiri soil	Zeyarthiri soil
Moisture	1.23	0.70
pH1; 2.5w	5.6	5.26
Texture	Silty loam	Silty loam
Organic Carbon (%)	2.42	2.17
Total N (%)	0.16	0.12
Available P (mg kg^{-1})	5.87	13.33
Available K (mg kg^{-1})	116.28	75.46
Ca (meq $100g^{-1}$)	13.49	5.37
Mg(meq $100g^{-1}$)	nd	nd
Water soluble SO_4 (meq $100g^{-1}$)	0.20	0.20
Available Zn (mg kg^{-1})	nd	2.63
Extractable B (mg kg^{-1})	1.5	1.2

nd = not detectable

Table 4.5 Mean comparison of plant growth characters in the pot experiment (dry season, 2017)

Item	Plant height (cm)	Total tillers $hill^{-1}$	Panicle length (cm)	TDM (t ha^{-1})
Pobbathiri soil	86.37	34.38a	22.07	21.33b
Zeyarthiri soil	88.77	31.09b	22.53	23.84a
LSD $_{0.05}$	7.45	2.89	0.63	1.19
T_1 (N.P.K)	87.2ab	30.83	22.43	22.93
T_2 (N.P.K + S)	86.43ab	34.5	22.13	22.94
T_3 (N.P.K +Zn)	87.68ab	34.17	22.10	21.66
T_4 (N.P.K + B)	89.03a	30.83	22.84	22.76
T_5 (N.P.K + S+Zn)	73.73b	33.00	22.27	22.61
T_6 (N.P.K + S+ B)	93.96a	33.5	22.57	22.30
T_7 (N.P.K +Zn+ B)	90.78a	34.67	22.37	23.45
T_8 (N.P.K +S+Zn+B)	91.72a	30.33	21.69	22.04
$LSD_{0.05}$	14.91	5.78	1.26	2.37
Pr > F				
Soil	ns	*	ns	**
Fertilizer	ns	ns	ns	ns
S*F	ns	ns	ns	ns
CV%	14.44	14.98	4.79	8.90

ns = not significant, * = significant at 5% level, ** = highly significant at 1% level

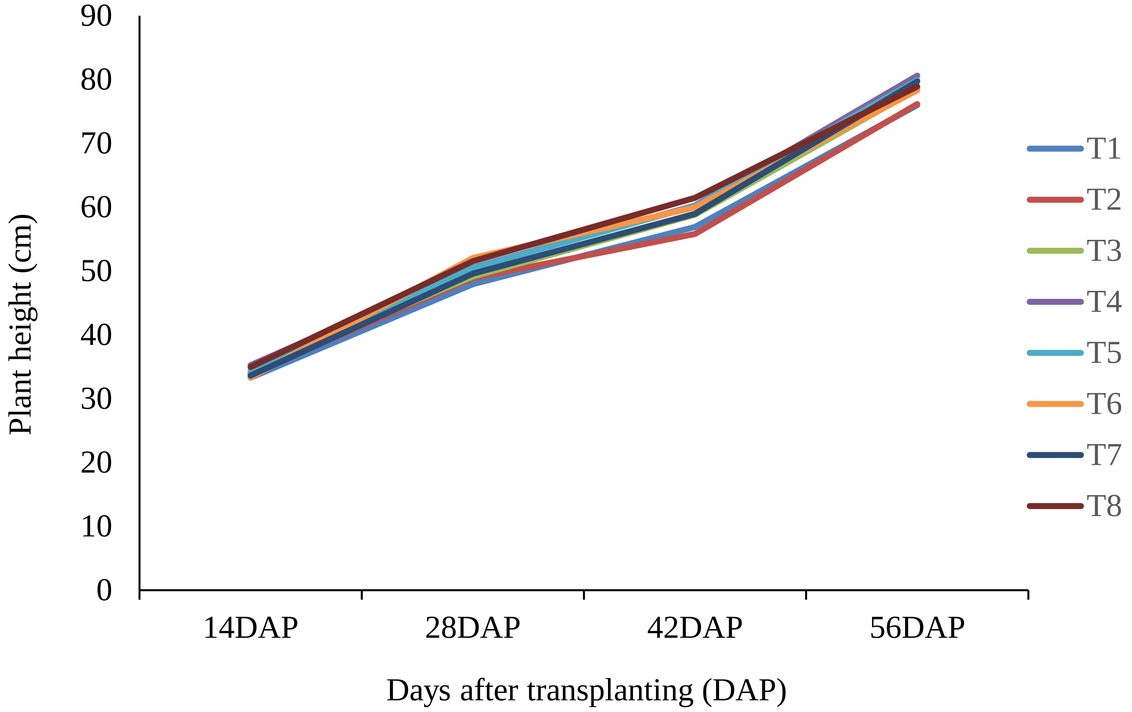


Figure 4.1 Plant height (cm) with time among the treatments at Pobbathiri soil (dry season, 2017)

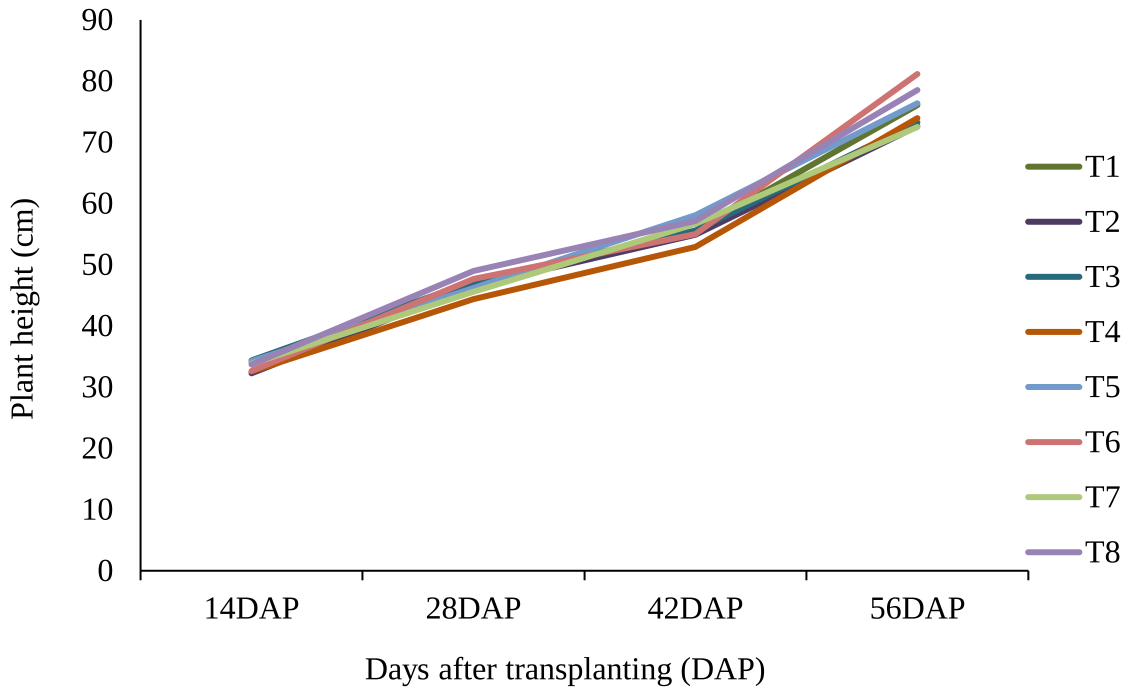


Figure 4.2 Plant height (cm) with time among the treatments at Zeyarthiri soil (dry season, 2017)

Table 4.6 Mean comparison of yield and yield components in the pot experiment (dry Season, 2017)

Item	Tiller hill^{-1}	Spikelet panicle^{-1}	Filled-grain%	1000-grain wt. (g)	Yield (t ha^{-1})
Pobbathiri Soil	17.25a	107.86b	88.80a	27.76	7.85b
Zeyarthiri soil	15.85b	122.98a	86.48b	27.70	8.24a
$LSD_{0.05}$	0.92	7.35	2.14	0.41	0.33
T_1 (N.P.K)	15.42b	116.21ab	82.59c	27.27b	7.81bc
T_2 (N.P.K + S)	17.25ab	110.17ab	87.48ab	27.61ab	7.99abc
T_3 (N.P.K +Zn)	16.83ab	104.01b	88.23ab	27.92ab	7.34c
T_4 N.P.K (+ B)	15.42b	122.48a	85.34bc	27.56ab	7.96abc
T_5 (N.P.K + S+Zn)	16.50ab	121.88a	88.54ab	27.76ab	8.33ab
T_6 (N.P.K + S+ B)	16.67ab	112.66ab	90.13a	28.14a	8.15abc
T_7 (N.P.K +Zn+ B)	17.33a	117.20ab	88.80ab	27.67ab	8.49 a
T_8 (N.P.K +S+Zn+B)	17ab	118.75a	90.03a	27.91ab	8.52 a
$LSD_{0.05}$	1.85	14.71	4.29	0.82	0.67
Pr > F					
Soil	**	**	*	ns	*
Fertilizer	*	ns	**	ns	*
S*F	ns	ns	ns	ns	ns
CV%	9.47	10.81	4.15	2.49	7.06

ns = not significant, * = significant at 5% level, ** = highly significant at 1% level

LSD $_{0.05}$ = 2.62

P>F = ns

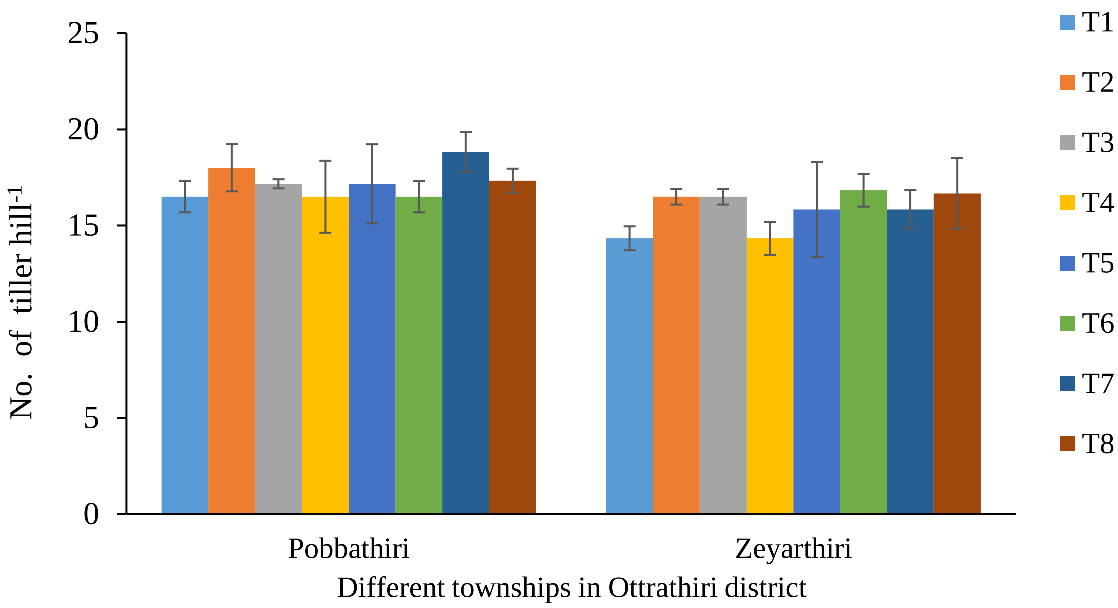


Figure 4.3 Mean comparison of number of tiller hill^{-1} among the treatment based on different soils (dry season, 2017)

LSD $_{0.05}$ =6.06

P>F = *

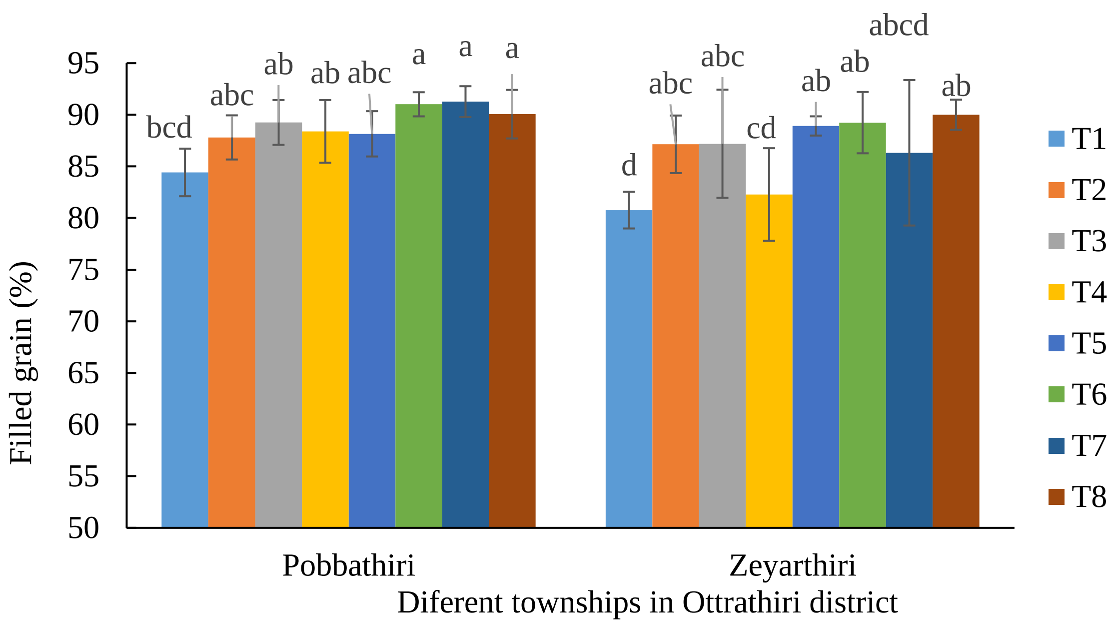


Figure 4.4 Mean comparison of filled grain percent among the treatment based on different soils (dry season, 2017)

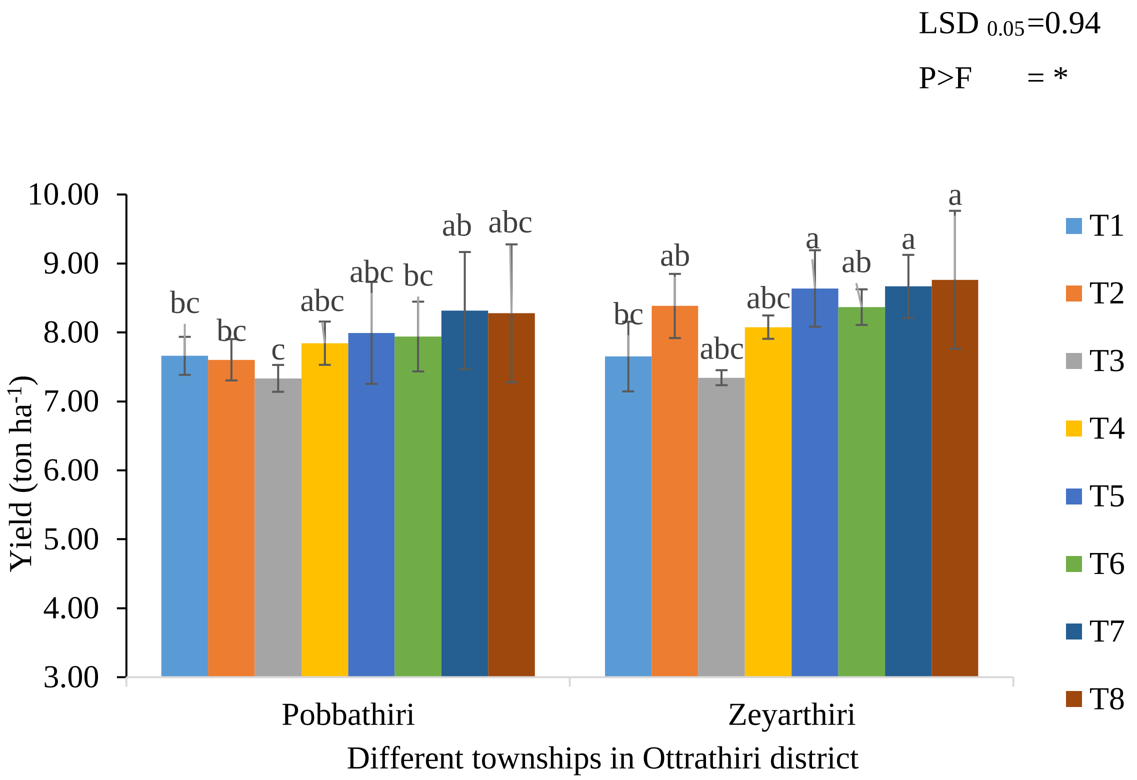


Figure 4.5 Mean comparison of yield (ton ha^{-1}) among the treatments based on different soils (dry season, 2017)

4.2.3.3 Filled grain percent

Filled grain percent among treatments based on location were shown in Figure (4.4). The highest filled grain percent found in order was T_7 >T_6>T_8 and the lowest was in T_1 at Pobbathiri soil whereas the highest was found in T8 at Zeyarthiri soil. The lowest filled grain percent was observed in T_1 treatment in both soils. Filled grain percent increased 9 percent in Zeyarthiri soil whereas 6 percent in Pobbathiri soil among treatments. In comparison between soils, the filled grain percent in Pobbathiri soil was greater than that of Zeyarthiri, soil. It was shown in Table (4.4). It might be due to the effect of K which was found more in the Pobbathiri farmer's field than Zeyarthiri soils.

4.2.3.4 Grain yield (ton ha^{-1})

The most important parameter of the experiment is yield per unit area. It was described in Figure (4.5). The highest yield was found in T_8 at both soils, and the lowest was found at T_1 in Zeyarthiri soil and T_3 in Pobbathiri soil. It may be an effect of spikelet number. The number of spikelets panicle^{-1} in T_3 of farmer soil was lesser than T_1 leading in lower yield than that of S_1T_1, but it is not significant.

Yield increased 0.62 ton ha^{-1} in Pobbathiri soil; however, 1.11 t ha^{-1} increased in Zeyarthiri soil by adding complete tested nutrients over NPK only treatment. It indicated the efficiency of micronutrient is tremendous in Zeyarthiri soil than the Pobbathiri field. However, the pronounce effect of addition nutrients (S+Zn+B) agree with the finding of Dash et al, (2015).

4.2.4 Fertilizer use efficiency in pot experiment (dry season, 2017)

4.2.4.1 Agronomic efficiency (AE)

Fertilizer use efficiency (Agronomic efficiency) of adding minor nutrients are described in Table (4.7). The response of treated nutrients was shown in this table. S and Zn alone have no response in Pobbathiri soil, but its effect can be seen in Zeyarthiri soil. The effect of B can be seen clearly in both soils. In two element combination treatments, Zn + B combination can give the highest yield and S+ Zn combination is more response than S + B combination treatment. In overall treatments, the highest yield can be seen in treatment on plus three combinations. It can give 0.865 ton ha^{-1} yield increased. (17.3 basket ac^{-1}).

In studying Agronomic efficiency, the highest was found in boron adding, and the lowest was found in S adding. Similar finding was observed by Fageria (2006). However, by combination with another nutrient, Zn, and Zn + B combination is the highest in agronomic efficiency in Pobbathiri soil.

4.2.4.2 Partial factor productivity (PFP)

The partial factor productivity of this experiment was shown in following (Table 4.8). In every treatment, partial factor productivity of specific nutrient on in Zeyarthiri soil is larger than that of Pobbathiri soil. Among the treatment, PFP is highest in B trated plot and lowest in Sulfur addition plot. In combination two elements, Zn+B combination has the largest PFP, and the lowest can be found in S and Zn combination.

The partial factor productivity of major nutrients was increased by adding all tested nutrients (complete) together with them. It resulted the PPF of major nutrient increase 4.08 in Pobbathiri soil and 7.7 in Zeyarthiri soil.

4.2.5 Soil nutrient level after harvesting in pot experiment (dry season, 2017)

The initial nutrient level in this experiment is few different in macronutrients and micronutrients between the soils. The content of major (N,P,K) and S were more in Zeyarthiri soil however the organic carbon and boron content were more in Pobbathiri soil. However the major nutrient level (N,P,K) and boron remaining in the soil after harvesting is nearly the same but remained Zn level in Zeyarthiri soil is higher than that of Pobbathiri soil. It is described in Appendix (6) and (7). After the pot experiment in dry season, next investigations were carried out in the field on farmer's soil at Pobbathiri Township and Zeyarthiri Township during rainy season (wet season) 2017.

This experiment was conducted at Set Set Yo farm in Pobbathiri Township. This farm is a prominent rice-growing area of the township.

4.3 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation (Pobbathiri experiment in wet season, 2017)

4.3.1 Physicochemical properties of experimental soil in Pobbathiri experiment (wet season, 2017)

As the soil test result of experiment were the percentage of sand, silt and clay were 27, 54 and 18 respectively so it can be classified as silt loam and its pH is the moderately acid condition. Organic carbon percent of it was medium level, but major nutrient N, P, and K were low. Although the level of secondary element Ca is in medium, but the level of Mg is very low. Moreover, water-soluble sulphate and extractable B are also low. In these soil, available Zn cannot be determined since it may be very low in level (Table 4.9). This area is a prominent rice area in Pobbathiri Township with high cropping intensity (153.18) (DOA, 2006). From the soil test result, the fertility level of this rice field is low in general. It may be because of its high cropping intensity and insufficient fertilizer use by farmers on those fields in the previous years.

Table 4.7 Agronomic efficiency (AE) in pot experiment (dry season, 2017)

Soil	Treatments	Yield (kg ha^{-1})	Differences (kg ha^{-1})	Applied nutrient (kg ha^{-1})	Agronomic Efficiency
Pobbathiri	T_1 (N.P.K)	7660	_	_	_
	T_2 (N.P.K + S)	7600	_	30	_
	T_3 (N.P.K +Zn)	7330	_	5	_
	T_4 (N.P.K + B)	7840	180	3	60
	T_5(N.P.K+ S+Zn)	7990	330	30+5	9.43
	T_6 (N.P.K + S+ B)	7940	280	30+3	8.49
	T_7 (N.P.K +Zn+ B)	8320	660	5+3	82.5
	T_8(N.P.K S+Zn+B)	8280	620	30+5+3	16.32
Zeyarthiri	T_1 (N.P.K)	7650	_	_	_
	T_2 (N.P.K + S)	8180	530	30	17.67
	T_3 (N.P.K +Zn)	7840	190	5	38
	T_4 (N.P.K + B)	8080	430	3	143.33
	T_5 (N.P.K + S+Zn)	8660	1010	30+5	28.86
	T_6 (N.P.K + S+ B)	8370	720	30+3	21.82
	T_7 (N.P.K +Zn+ B)	8670	1020	5+3	127.5
	T_8(N.P.K S+Zn+B)	8760	1110	30+5+3	29.21

Table 4.8 Partial factor productivity in pot experiment (dry season, 2017)

Soil	Treatments	Yield (kg ha^{-1})	Major Nutrient PFP	Tested Nutrient PFP	Total Nutrient PFP
Pobbathiri	T_1 (N.P.K)	7660	50.39	-	50.39
	T_2 (N.P.K + S)	7600	50.00	253.33	41.76
	T_3 (N.P.K +Zn)	7330	48.22	1466.00	46.69
	T_4 (N.P.K + B)	7840	51.58	2613.33	50.58
	T_5 (N.P.K + S+Zn)	7990	52.57	228.29	42.73
	T_6 (N.P.K + S+ B)	7940	52.24	240.61	42.92
	T_7 (N.P.K +Zn+ B)	8320	54.74	1040.00	52.00
	T_8(N.P.K+S+Zn+B)	8280	54.47	217.89	43.58
Zeyarthiri	T_1 (N.P.K)	7650	50.33	-	50.33
	T_2 (N.P.K + S)	8180	53.82	272.67	44.95
	T_3 (N.P.K +Zn)	7840	51.58	1568.00	49.94
	T_4 (N.P.K + B)	8080	53.16	2693.33	52.13
	T_5 (N.P.K + S+Zn)	8660	56.97	247.43	46.31
	T_6 (N.P.K + S+ B)	8370	55.07	253.64	45.24
	T_7 (N.P.K +Zn+ B)	8670	57.04	1083.75	54.19
	T_8(N.P.K+S+Zn+B)	8760	57.63	230.53	46.11

4.3.2 Plant growth character (wet season, 2017)

In this experiment, plant growth character such as plant height, total tiller in maximum tillering stage, panicle length, and total dry matter were studied. The results of plant growth characters of experiments were found in Table (4.10).

The plant height data were collected in two-week interval started from 14 days after transplanting. Plant height of treatments were shown in Figure (4.6), however, there were no significant differences. The complete nutrients plot (T_8) provide the highest plant height, and the lowest was found in NPK only treatment (T_1). Adequate nutrient results in good plant growth character, especially in height. It was showed in Figure (4.6). Although the tiller was not significantly different with treatments, the highest result was found in Zn addition treatment. But T_6 (+ S and B) treatment was at in lowest level in Tillering (Table 4.10). There were not found significantly differences in panicle length with treatments. It may mainly depend on major nutrients but on the minor. It was shown in Figure (4.10).

4.3.3 Yield and yield component in Pobbathiri experiment (wet season, 2017)

Yield is a complex plant characteristic and influenced by many yield component and their interaction. The most important yield component and associated plant characteristics are several panicles or heads, no. of spikelets panicle^{-1}, thousand grain weight and spikelet sterility in cereals. Yield and yield component of the experiment was described in Table (4.11).

4.3.3.1 Number of effective tillers hill^{-1}

Effective tiller is one of the important components of yield. . In this experiment, the greatest effective tiller was found in T_8, and the lowest was found in T_1 (NPK) and T_3 (NPK +Zn). It shows Zn cannot effect on the number of tiller but combining with S and B, it can increase the number of effective tillers in the plant. Thus by adding all required nutrients, the effective tiller can be increased by 25.4 percent.

4.3.3.2 Number of spikelets panicle^{-1}

The spikelet panicle^{-1} is also a crucial component of yield; however, it cannot be seen as a significant difference in the experiment. Although significantly differences have not been met, highest spikelet panicle^{-1} at T_8 (NPK+S+Zn+B) and lowest at T_5 (NPK +S +Zn) were found in this experiment. The second largest figure was shown in $T_{4,}$ followed by T_7 (NPK+Zn+B). It may be due to the effect of boron. Boron has positive effect on spikelet panicle^{-1} that’s the important character of crop yield.

Table 4.9 Physicochemical properties of experimental soil in Pobbathiri experiment (wet season, 2017)

Particular		Rating
Moisture%	4.67	
pH	5.57	Moderately acid
Texture	27:54:18	Silt Loam
Organic Carbon (%)	3.34	Medium
Total N (%)	0.17	Low
Available P(mg kg^{-1})	2.47	Low
Available K(mg kg^{-1})	78.64	Low
Ca (meq100g^{-1})	13.29	Medium
Mg (meq100g^{-1})	0.70	Very Low
Water-soluble SO_4 (meq100g^{-1})	0.35	Low
Available Zn (mg kg^{-1})	nd	Very Low
Extractable B (mg kg^{-1})	0.85	Low

nd = not detectable

4.3.3.3 Filled-grain percent with treatments

Filled grain percent in this experiment was shown in Figure (4.7). In this experiment the highest value resulted from T_4 followed by $>T_6>T_7>T_5>T_8$ and the least value can be found in T_1, and $T_2 = T_3$ are in equal. It was significantly different from treatments. The result showed the contribution of B in filled grain percent in rice would be somewhat important. The effect on filled grain % by B might be due to the positive effect of B on reproductive physiology need for grain formation.

4.3.3.4 Thousand grain weight (g)

Generally, thousand grain weight was the character of variety, so there were not significantly differences among treatments. Just few differences among treatments was shown in Table (4.11).

4.3.3.5 Yield per unit area (ton ha^{-1})

The most important parameter of the experiment is yield per unit area. Crop yield is determined by yield component which is in cereal; the number of panicles $hill^{-1}$, spikelet $panicle^{-1}$, filled grain percent and grain weight. Yield component is formed throughout the plant cycle. Hence it is very important to have good knowledge of different growth stages during the crop cycle of a plant (Yoshida, 1981). Yield is the most important measurement of crop's plant economic value. It is defined as the amount of specific substance produced, e.g., grain, straw, total dry matter per unit area and so on. Grain yield means the weight of cleaned and dried grain harvested from a unit area. For cereal crops, grain yield is usually expressed either kg per ha or metric t ha^{-1} at 13 to 14% in moisture (Fageria, 2009). The crop yield is finally derived from its component. The yield of experiment varying with treatments are shown in Figure (4.8).

In this experiment, plant performance among treatments were not different. However, the yield was highest in T_8, followed by T_4 and T_5 and the lowest was found in T_1. Addition of Complete nutrient (T_8) gave the highest value of yield, and the lowest was found in (T_1). Although it is not significantly different, it can increase 1.1 ton ha^{-1} and the increase percent of twenty-one. The treatment of T_2, Application of sulphur can increase yield at 6.98 percent to control. Likewise, the yield of T_3, T_4, T_5, T_6, T_7, and T_8 are higher 15.66, 16.98, 16.98, 14.53, 15.09, and 20.56 than control in percent.

Table 4.10 Mean comparison of plant growth character in Pobbathiri experiment (wet season, 2017)

Treatments	Plant height (cm)	Total Tiller hill^{-1}	T.D.M (t ha^{-1})	Panicle length (cm)
T_1 (N.P.K)	68.00	31.37 bc	13.64 ab	17.50
T_2 (N.P.K + S)	71.00	31.67 bc	14.66 a	17.67
T_3 (N.P.K +Zn)	71.67	36.33 a	14.97 a	17.67
T_4 (N.P.K + B)	74.33	32.67 abc	15.35 a	16.77
T_5 (N.P.K + S+Zn)	71.67	32.67 abc	12.01 b	16.60
T_6 (N.P.K + S+ B)	70.33	29.50 c	14.75 a	16.50
T_7 (N.P.K +Zn+ B)	71.33	33.91 ab	14.43 a	17.33
T_8 (N.P.K +S+Zn+B)	74.67	35.58 ab	14.15 a	17.40
$LSD_{0.05}$	10.70	4.22	1.89	1.51
Pr > F	ns	ns	*	ns
CV%	8.53	7.31	7.59	5.04

ns = not significant, * = significant at 5% level, ** = highly significant at 1% level

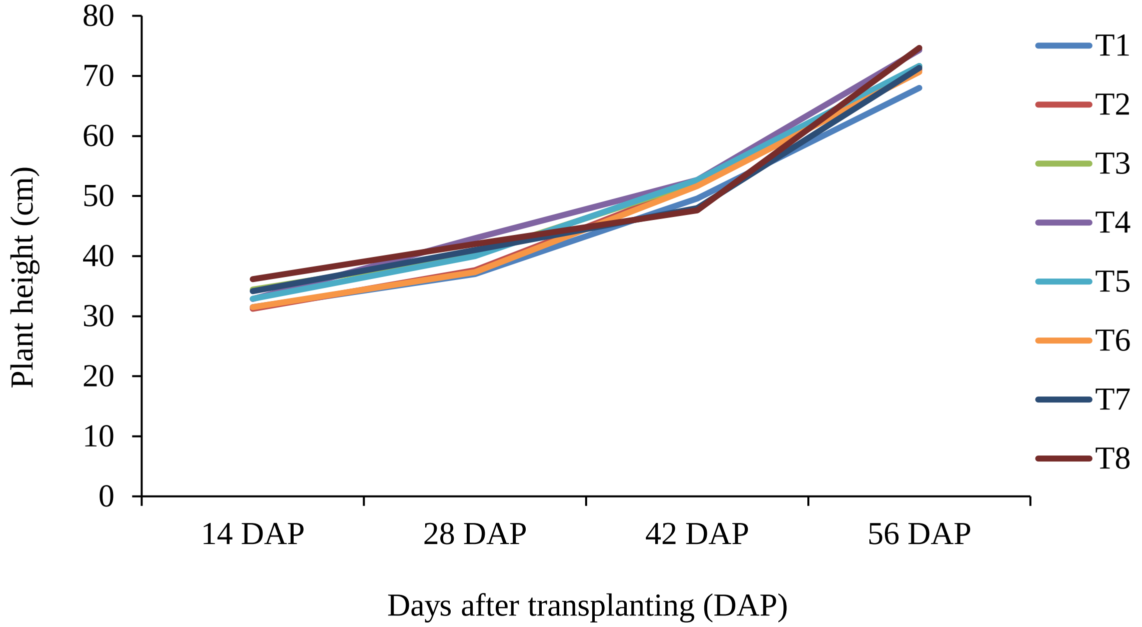


Figure 4.6 Plant height (cm) with time among the treatments in Pobbathiri experimental soil (wet season, 2017)

4.3.4 Fertilizer use efficiency in Pobbathiri experiment (wet season, 2017)

4.3.4.1 Agronomic efficiency (AE)

Fertilizer use efficiency (Agronomic efficiency) of adding macronutrient and micronutrient was shown in Table (4.12). Agronomic efficiency of micronutrient was higher than that of macronutrient although yield difference of these elements was a few because they were applied in a small amount of nutrients. However, the highest yield was obtained by using all tested nutrients together with major nutrients (N, P, K) owing Agronomic Efficiency of about thirty. It was shown in Table (4.12). The highest AE was found in B treated plot followed by T_3 (Zn treated) plot. Fageria (2006) observed the highest efficiency of boron among micronutrients in rice.

4.3.4.2 Partial factor productivity (PFP)

Partial factor productivity is calculated based on applied nutrients to total yield. The highest PFP of individual nutrient was found in T_4 since the applied nutrient was as low as 3 kg ha^{-1}B. The lowest was found in T8 as it is applied all nutrients in the total amount of 38 kg ha^{-1} (Table 4.13). Although total added nutrient's PPF was not greater, the major nutrient's efficiency was found greater in T_8 than T_1which is a plot received the major nutrient alone. The increase value of 7.24 was recorded in T_8 over T_1.

4.3.5 Soil nutrient after harvesting in Pobbathiri experiment (wet season, 2017)

Soil nutrient status recorded after harvesting showed that there are not too changes in nutrients level between initial and postharvest situation except in Boron content. This result showed the rate of Boron may be over plant needs and thus it can be maintained its level for next crops. And it can be noted that fertility level was maintained by applied nutrients in crop growing. The figure described in Appendix (8).

Table 4.11 Mean comparison of yield and yield component of Pobbathiri Experiment (wet season, 2017)

Treatments	Effective Tiller hill^{-1}	Spikelet panicle^{-1}	Filled-grain%	1000- grain wt. (g)	Yield (t ha^{-1})
T_1(NPK)	6.83	66.87	77.63 d	31.97	5.30 c
T_2(NPK + S)	7.42	63.97	82.80 c	31.73	5.67 bc
T_3(NPK+Zn)	6.83	65.97	82.80 c	31.40	6.13 ab
T_4(NPK+B)	8.42	76.63	90.15 a	30.97	6.20 ab
T_5(NPK+S+Zn)	7.17	62.60	87.80 ab	31.61	6.20 ab
T_6(NPK+S+B)	8.00	66.07	89.60 ab	28.71	6.07 ab
T_7(NPK+Zn+B)	7.75	74.10	88.73 ab	32.17	6.10 ab
T_8(NPK+S+Zn+B)	8.57	78.33	84.93 bc	31.06	6.39 a
LSD $_{0.05}$	1.49	16.27	4.79	1.72	0.72
Pr > F	ns	ns	**	ns	ns
C.V %	11.18	13.41	3.2	3.12	6.85

ns = not significant, * = significant at 5% level, ** = highly significant at 1% level

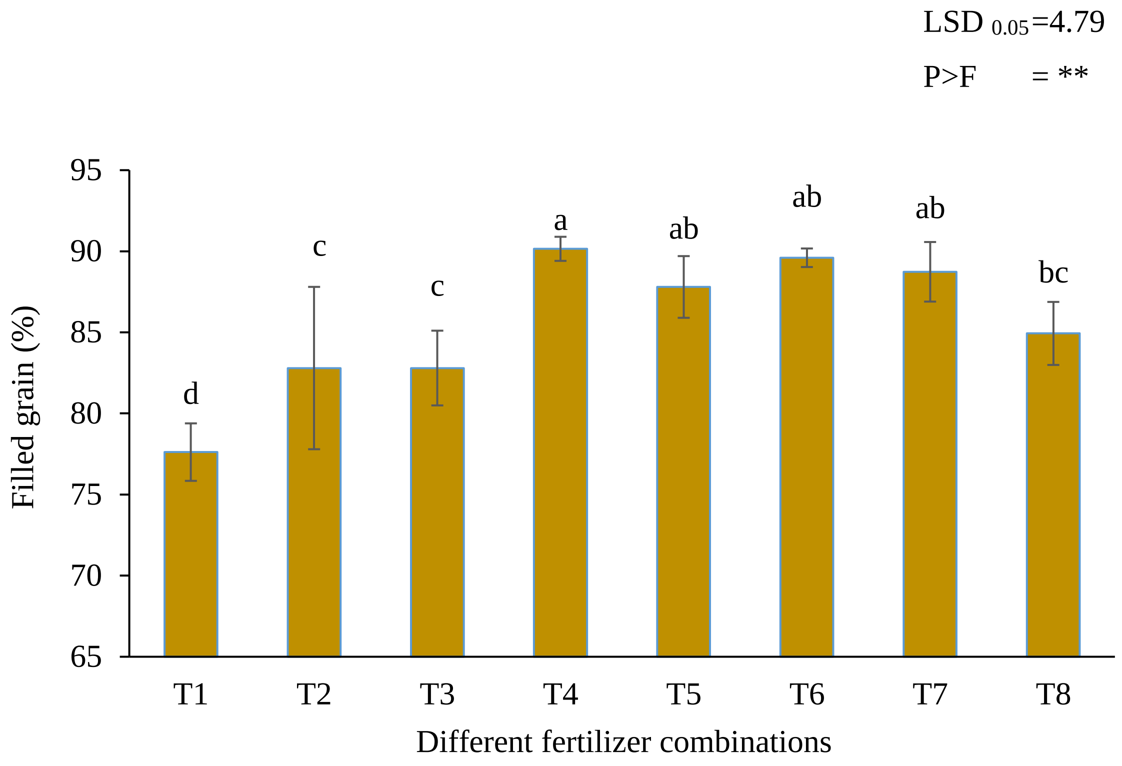


Figure 4.7 Mean comparison of filled grain percent among the treatments in Pobbathiri experiment (wet season, 2017)

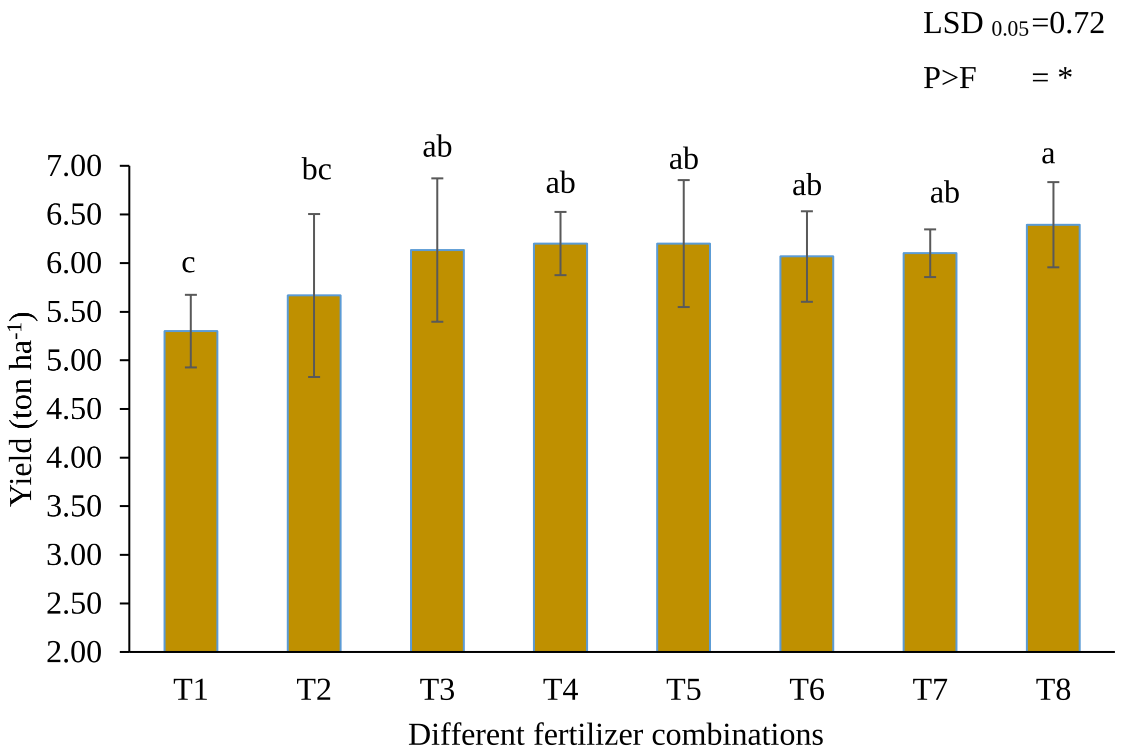


Figure 4.8 Mean comparison of yield ton ha^{-1} among the treatments in Pobbathiri experiment (wet season, 2017)

Table 4.12 Agronomic efficiency (AE) in Pobbathiri experiment (wet season, 2017)

Treatments	Yield (kg ha^{-1})	Differences (kg ha^{-1})	Applied nutrient (kg ha^{-1})	Agronomic Efficiency
T_1 (N.P.K)	5300	-	-	-
T_2 (N.P.K + S)	5670	370	30	12.33
T_3 (N.P.K +Zn)	6130	830	5	166
T_4 (N.P.K + B)	6200	900	3	300
T_5(N.P.K + S+Zn)	6200	900	30+5	25.71
T_6 (N.P.K + S+ B)	6070	770	30+3	23.33
T_7(N.P.K+Zn+ B)	6100	800	5+3	100
T_8(N.P.K+S+Zn+B)	6400	1100	30+5+3	28.95

Table 4.13 Partial factor productivity (PFP) in Pobbathiri experiment (wet season, 2017)

Treatment	Yield (kg ha^{-1})	Major Nutrient PFP	Tested Nutrient PFP	Total PFP
T_1 (N.P.K)	5300	34.87	-	34.87
T_2 (N.P.K + S)	5670	37.30	189.00	31.15
T_3 (N.P.K +Zn)	6130	40.33	1226.00	39.04
T_4 (N.P.K + B)	6200	40.79	2066.67	40.00
T_5 (N.P.K + S+Zn)	6200	40.79	177.14	33.16
T_6 (N.P.K + S+ B)	6070	39.93	183.94	32.81
T_7(N.P.K +Zn+ B)	6100	40.13	762.50	38.13
T_8(N.P.K+S+Zn+B)	6400	42.11	168.42	33.68

4.4 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation in Zeyarthiri experiment (wet season, 2017)

As above mentioned, this experiment was also conducted at the same time with Pobbathiri experiment during rainy season (wet season), 2017. The same cultivar and the same treatments were used as section 4.2. The data collected from the experiment was also the same from Pobbathiri experiment.

4.4.1 Physicochemical properties of experimental soil in Zeyarthiri experiment (wet season, 2017)

This experiment was carried out at Thitat village tract in Zeyarthiri Township. It is also a main rice growing area of the respective township. The experiment site was the moderately acid condition, and soil physical property in texture was silty loam containing sand: silt: clay ratio of 14:63:22 in percent. The organic carbon, total N, and available Ca were found at medium level. However other nutrients such as available (P and SO_4) were at a low level and Mg and B were found in very low level. There cannot be detected in available Zn; probably it contains too low in experimental soil (Table 4.14).

4.4.2 Plant growth characters in Zeyarthiri experiment (wet season, 2017)

Plant growth character of this experiment was found in Table (4.15). There was no significantly difference in plant growth characters except in panicle length. Quddus as cited in Sarker, Ali, Rahman, and Khan (2013) also found the similar result that's not significant in plant growth characters by treatments.

The plant height data were collected in two-week interval started from 14 days after transplanting. There were not significantly different. It might be determined by major nutrients but not by other minor nutrient treatments. However, in this experiment, the highest plant height was found in T_4, and the lowest was found in T_1 in this experiment. The plant height was slightly different among treatments. Plant height with treatments as time was shown in Figure (4.9). The total tillers in the crop is also one of the characters of crop growth, although it cannot determine the yield. However, the number of total tillers of T_4 was highest in these experiments. The lowest value was found in T_1 and T_6 (Table 4.15).

One of the growth characters of the crop is total dry matter (TDM). In this experiment, the highest TDM was found in T_4 and lowest value was in T_2 (NPK+ S addition), having slightly lower than that of T_1. The character of TDM is mainly determined by major nutrient N and K**.**

Panicle length is the most desirable character of the crop. Figure (4.10) shows the trend of panicle length among treatments. The lowest was found in T_1, and the highest level over trend was found in T_4 and T_5. Overall treatments in the experiment, the nutrient can give higher panicle length significantly at the level of 0.05. The differences of panicle length among treatments were found significantly. The length was higher than T_1 by adding boron nutrient. Addition of S together with Zn or B and adding all nutrients (S+Zn+B) were found greater effect over T_1.

4.4.3 Yield and yield component in Zeyarthiri experiment (wet season, 2017)

The most important factor of the crop is yield and its contributing components. In this experiment, the result showed that filled grain percent and yield were significantly different among treatments. Other component factors such as number of effective tillers, number of spikelets panicle^{-1}, and thousand grain weight were not significantly different among the treatments (Table 4.16).

4.4.3.1 Number of effective tillers hill^{-1}

There were no differences in number of effective tillers with treatments. Only slightly differences among treatments were obtained in this experiment. Table (4.16) showed the difference of number of effective tiller hill^{-1} among the treatments.

4.4.3.2 Number of spikelets panicle^{-1}

There were no significant differences among treatments in spikelet number. In fact, number of spikelets panicle^{-1} is major contributes to yield due to its effectiveness determining the level of yield. However, it looks like more depend on major nutrient for contribution in yield than others. By adding minor nutrients can't give much more increased yield. Hence slightly differences among treatments can be found in this experiment (Table 4.16).

4.4.3.3 Filled grain percent

In this study, filled grain percent was significantly different among treatments. The result showed that adding minor nutrients (S, Zn, and B) have positive effect on filled grain percent. The highest filled grain will be gained by Zn or B and a combination of Zn and B. The nutrient S can give higher filled grain percent but just a little. The effect of Zn and B were found clearly (Figure 4.11).

Table 4.14 Physicochemical properties of experimental soil in Zeyarthiri experiment (wet season, 2017)

Particular		Rating
Moisture%	6.47	
pH	5.54	Moderately acid
Texture	14: 63: 22	Silty Loam
O.C (%)	3.03	Medium
Total N (%)	0.21	Medium
Available P(mg kg^{-1})	5.60	Low
Available K(mg kg^{-1})	213.75	High
Ca (meq100g^{-1})	11.41	Medium
Mg (meq100g^{-1})	0.71	Very Low
Water-solubleSO_4(meq100g^{-1})	0.55	Low
Available Zn(mg kg^{-1})	nd	nd
Extractable B (mg kg^{-1})	0.24	Very Low

Table 4.15 Mean comparison of plant growth characters in Zeyarthiri experiment (wet season, 2017)

Treatments	Plant height (cm)	Tiller $hill^{-1}$	TDM (t ha^{-1})	Panicle length (cm)
T_1 (N.P.K)	93.5	33.27	14.33	21.83 c
T_2 (N.P.K + S)	94	34.10	14.07	22.50 bc
T_3 (N.P.K +Zn)	101	34.27	15.38	22.67 bc
T_4 (N.P.K + B)	103	35.37	16.85	24.0 a
T_5 (N.P.K + S+Zn)	101	34.40	15.90	24.0 a
T_6 (N.P.K + S+ B)	96	33.27	15.60	23.23 ab
T_7 (N.P.K +Zn+ B)	99	34.0	15.70	22.50 bc
T_8 (N.P.K +S+Zn+B)	99.33	34.33	16.60	23.17 ab
$LSD_{0.05}$	11.53	1.77	2.20	1.27
Pr>F	ns	ns	ns	*
C.V %	6.57	2.96	8.09	3.18

ns = not significant, * = significant at 5% level, ** = highly significant at 1% level

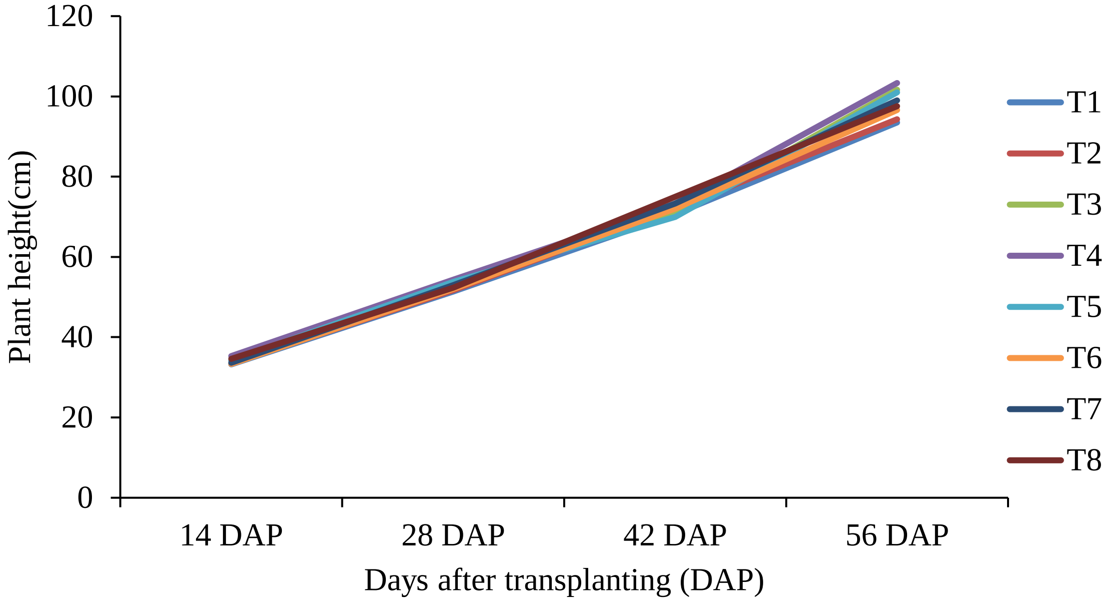


Figure 4.9 Plant height (cm) with time among the treatments at Zeyarthiri experimental soil (wet season, 2017)

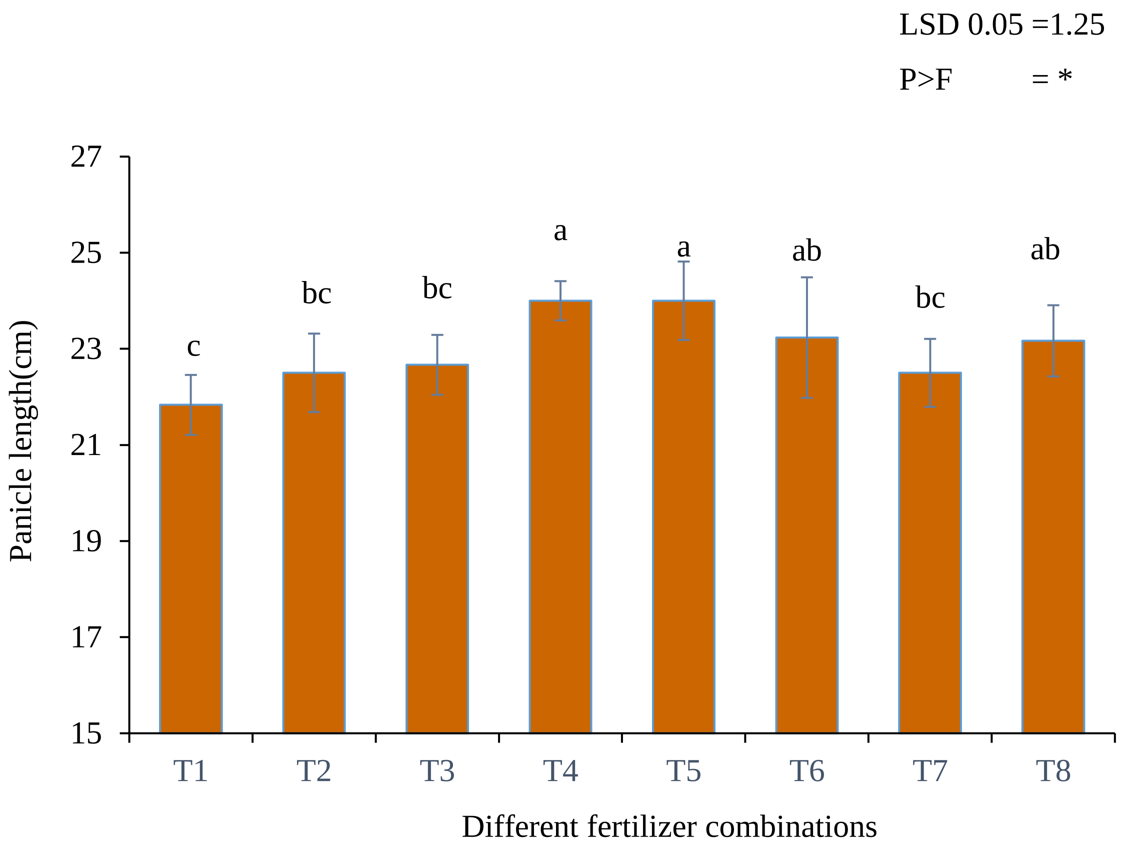


Figure 4.10 Mean comparison of panicle length among the treatments in Zeyarthiri experiment (wet season, 2017)

4.4.3.4 Thousand grain weight

Thousand grain weight was mostly characterized by variety; thus, no difference was found among treatments (Table 4.16).

4.4.3.5 Yield per unit area (t ha^{-1})

The most important parameter of the experiment is yield per unit area which shown in Figure (4.12). Most of the yield contributing factor were not significantly different, however, the yield was found significant differences among treatments in this experiment.

The grain yield responded significantly to the applied micronutrients. The treatment containing, sulphur, zinc and boron together with NPK (T_8) produced highest grain yield (7.63 t ha^{-1}), and the lowest yield (6.51 t ha^{-1}) was found in T_1. Among the treatments, T_7 gave the approximately equal to the yield of T_8 hence, the importance of S is lesser than that of the rest two elements. However, an additional plot of sulphur can give10.9 percent yield increased to control. In other treatments fromT_3 to$T_{8,}$ the percent increase in grain yield is 12.29, 13.52, 11.98, 8.90, 16.74, and 17.20 over T_1.

4.4.4 Fertilizer Use Efficiency in Zeyarthiri experiment (wet season, 2017)

4.4.4.1 Agronomic efficiency (AE)

Fertilizer use efficiency (Agronomic efficiency) of adding minor nutrients was described in Table (4.17). Economic Yield increased was not too much higher by the micronutrient application. However, the Agronomic Efficiency of the micronutrient is quite high since the applied rates of nutrients were low. In single nutrients application, the highest AE was found in B treatment, and the lowest can be seen in S treatment since the applied nutrient of S is as higher as 6 to 10 time than micronutrients. However, the Agronomic Efficiency of about thirty can be obtained by T_8, complete treatment (NPK+S+Zn+B) (Table 4.17). Importance of Zn and B were found. The highest AE was found in B treated plot follow by Zn. Similar result, the best nutrient utilization efficiency of boron was found by Fageria (2006).

4.4.4.2 Partial factor productivity (PFP)

In study point of specific nutrient, the highest partial factor productivity (PFP) was found in T_4 since the applied rate of this element was the lowest. The next highest PFP was found in T_3 and T_7.

Table 4.16 Mean comparison of yield and yield component in Zeyarthiri experiment (wet season, 2017)

Treatment	Effective tiller hill^{-1}	Spikelet panicle^{-1}	Filled grain%	1000-grain wt. (g)	Yield (t ha^{-1})
T_1(NPK)	7.08	108.13	78.04 d	28.07	6.51 b
T_2(NPK + S)	7.67	111.08	83.84 cd	27.37	7.22 a
T_3(NPK+Zn)	6.67	117.90	92.67 a	28.4	7.31 a
T_4(NPK+B)	7.92	113.57	92.17 b	28.27	7.39 a
T_5(NPK+S+Zn)	7.75	114.10	87.30 c	27.30	7.29 a
T_6(NPK+S+B)	7.67	110.67	91.67 b	28.67	7.09 ab
T_7(NPK+Zn+B)	7.42	109.57	96.43 a	28.40	7.60 a
T_8(NPK+S+Zn+B)	7.17	111.73	92.93 ab	29.37	7.63 a
LSD $_{0.05}$	1.45	17.97	3.69	1.59	0.63
Pr > F	ns	ns	**	ns	*
C.V%	11.16	9.16	2.36	3.22	5.01

ns $_=$ not significant, *$_=$ significant at 5% level, **$_=$ highly significant at 1% level

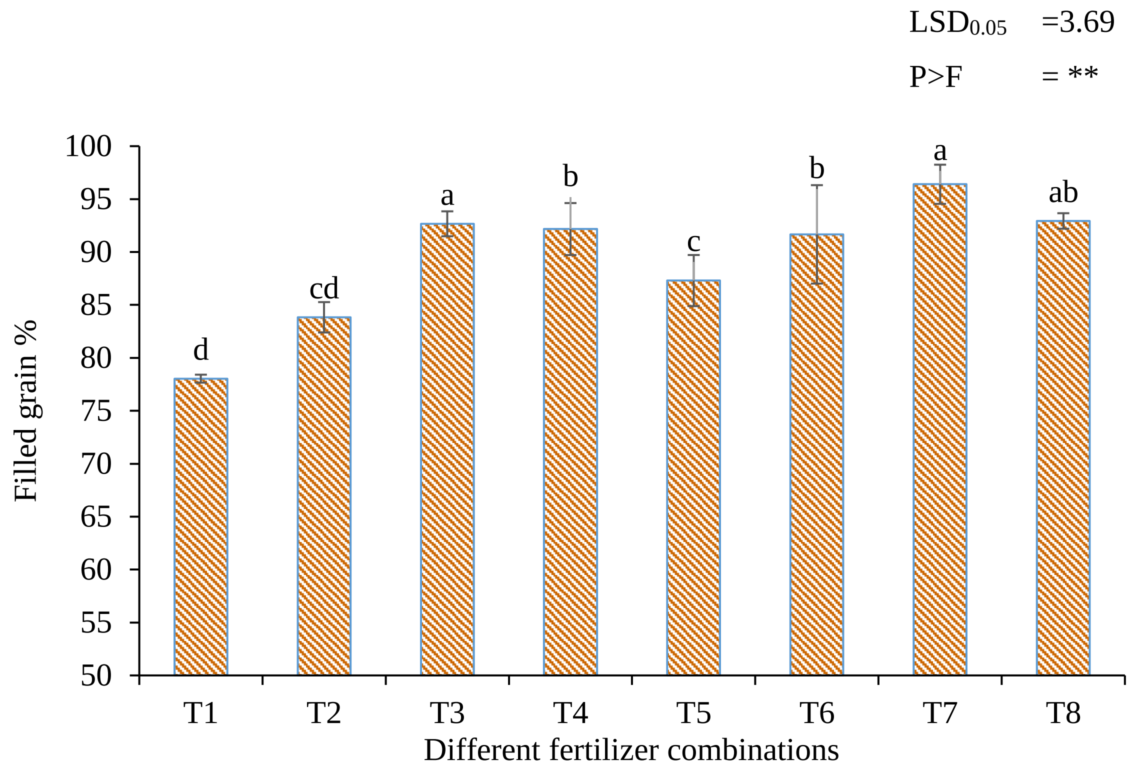


Figure 4.11 Mean comparison of filled grain percent among the treatments in Zeyarthiri experiment (wet season, 2017)

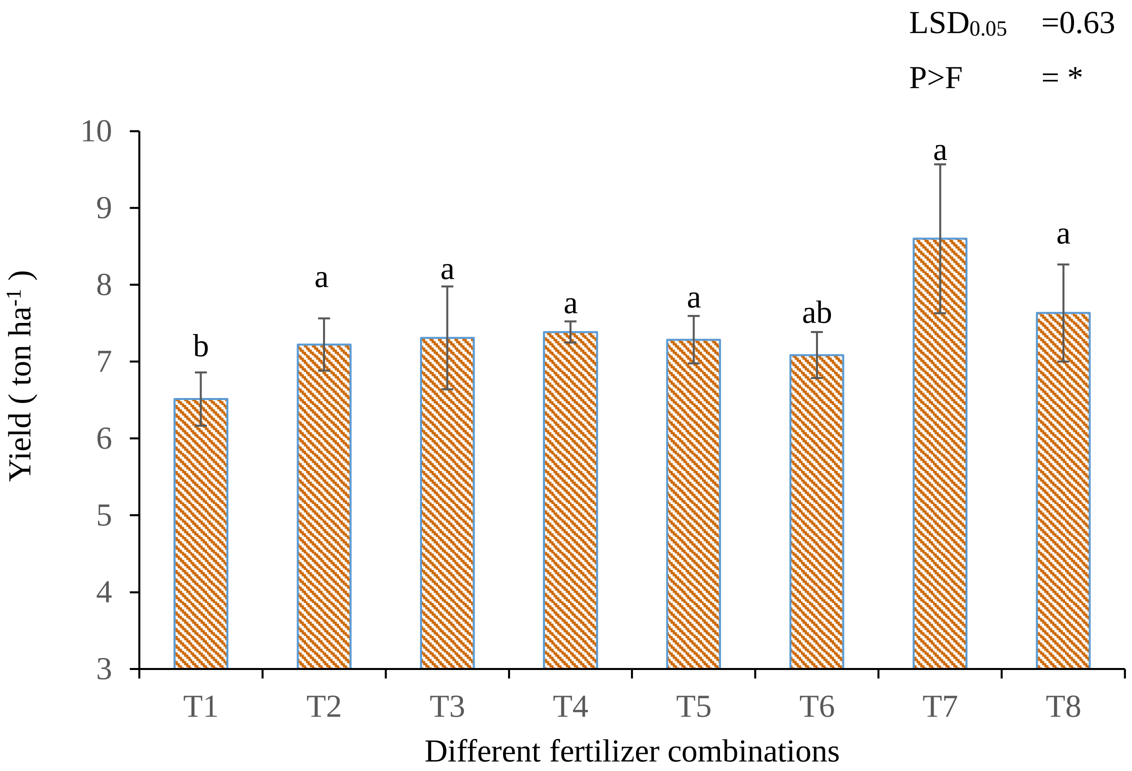


Figure 4.12 Mean comparison of yield ton ha^{-1} among the treatments in Zeyarthiri experiment (wet season, 2017)

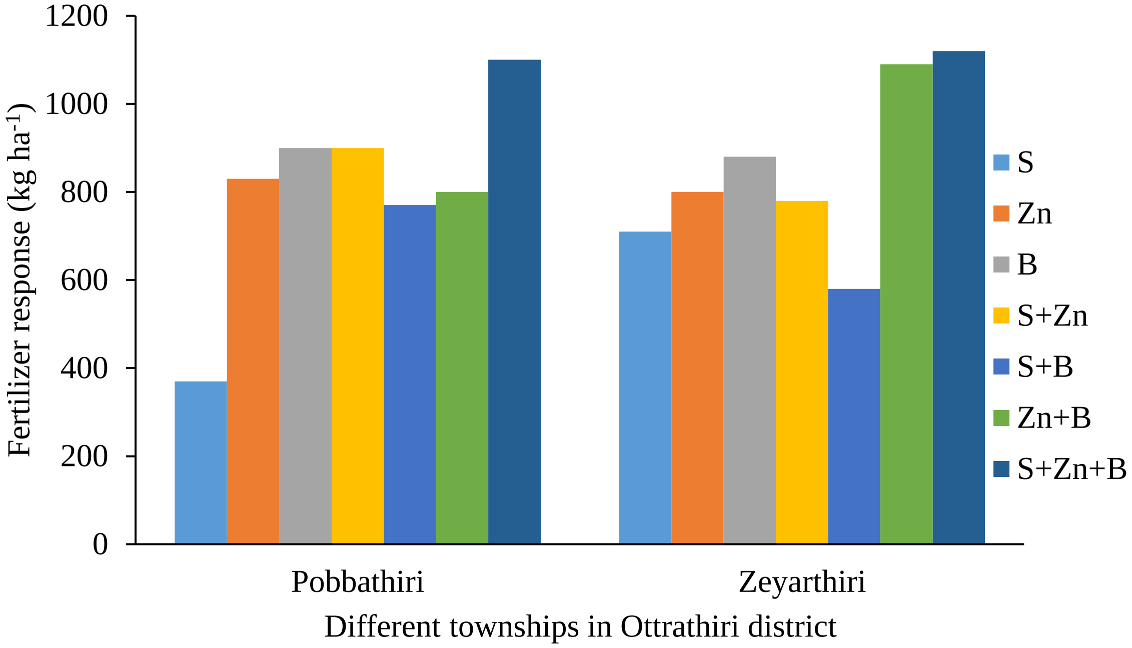


Figure 4.13 Yield response trend in two experiments wet season, 2017

The other treatments were almost the same in partial factor productivity of efficiency in this experiment. Although total added nutrient's PPF was not greater in T_8, the major nutrient's efficiency was found greater thanT_1 applied them alone. It increases 7.37 over control. In combination two elements, Zn+B combination has the largest PFP, and the lowest can be found in S + Zn combination. The result recorded in the experiment indicated the among the three nutrients applied efficiency of B was dominant, however, the maximum PFP of major nutrient NPK is obtained by complete treatments (Table 4.18).

4.4.5 Soil nutrient after harvesting in Zeyarthiri experiment (wet season, 2017)

Soil nutrient level after harvesting in experimental site is not remarkable different with initial stage since the applied nutrient amount is not too exceed amount that plant use, however, B content remaining in the soil is higher than that of initial stage. It can be survived in next crops without adding more. It was described in Appendix (9).

In comparison, all treatments in different locations, the response of S was higher in Zeyarthiri, but those of Zn and B were greater in Pobbathiri than in Zeyarthiri. Thus, it can be said the (T_2) S response was more prominent in Zeyarthiri experimental site however in combination of B and S gave lesser increased yield percent in Zeyarthiri. By the addition of Zn and B gave the higher yield response in Zeyarthiri if it is compare to Pobbathiri experiment. However, combining of all treatments gave the highest yield, and the greater effect was found in Pobbathiri in percent. The results revealed that the highest yield (6.4-7.6 t ha^{-1}) were recorded in T_8 in both experiments and lowest yield (5.3-6.5 t ha^{-1}) were recorded in T_1. Therefore, the present investigation suggests that T_8 must be the best to both locations in rice production.

4.5 Evaluation of Balanced Macronutrient and Micronutrient Fertilizer Application in Rice Cultivation (Pot experiment wet season, 2018)

This study was conducted to support previous research to be confirmed with plant nutrient uptake by plant analysis. Although the study focused on only yield and yield attribute data in previous seasons, nutrient uptake by the plant through plant analysis were additionally studied in this experiment. The experiment sites (rice land of Pobbathiri and Zeyarthiri Township) in previous research are under the same major soil type which is Gleysol and yield response trend are the same pattern so only one soil was used for study option in this experiment.

Table 4.17 Agronomic efficiency (AE) in Zeyarthiri experiment (wet season, 2017)

Treatments	Yield (kg ha^{-1})	Differences (kg ha^{-1})	Applied nutrient (kg ha^{-1})	Agronomic Efficiency
T_1 (N.P.K)	6510	-	-	-
T_2 (N.P.K + S)	7220	710	30	23.67
T_3 (N.P.K +Zn)	7310	800	5	160
T_4 (N.P.K + B)	7390	880	3	293.3
T_5(N.P.K+S+Zn)	7290	780	30+5	22.29
T_6(N.P.K+ S+ B)	7090	580	30+3	72.5
T_7(N.P.K+Zn+ B)	7600	1090	5+3	136.25
T_8(N.P.K+S+Zn+B)	7630	1120	30+5+3	29.47

Table 4.18 Partial factor productivity in Zeyarthiri experiment (wet season, 2017)

Treatments	Yield (kg ha^{-1})	Major Nutrient PFP	Tested Nutrient PFP	Total PFP
T_1 (N.P.K)	6510	42.83	0.00	42.83
T_2 (N.P.K + S)	7220	47.50	240.67	39.67
T_3 (N.P.K +Zn)	7310	48.09	1462.00	46.56
T_4 (N.P.K + B)	7390	48.62	2463.33	47.68
T_5 (N.P.K + S+Zn)	7290	47.96	208.29	38.98
T_6 (N.P.K + S+ B)	7090	46.64	214.85	38.32
T_7 (N.P.K +Zn+ B)	7600	50.00	950.00	47.50
T_8 (N.P.K +S+Zn+B)	7630	50.20	200.79	40.16

Table 4.19 Mean comparison of yield and yield response in the two experiments (wet season, 2017)

Treatment	Yield kg ha^{-1} (Zeyar)	Yield kg ha^{-1} (Pobba)	Differences in Pobbathiri	Differences in Zeyarthiri
T_1 (N.P.K)	6510	5300	-	-
T_2 (N.P.K + S)	7220	5670	370(6.98)	710(10.9)
T_3 (N.P.K +Zn)	7310	6130	830(15.66)	800(12.28)
T_4 (N.P.K + B)	7390	6200	900(16.98)	880(13.51)
T_5(N.P.K+S+Zn)	7290	6200	900(16.98)	780(11.98)
T_6 (N.P.K+ S+ B)	7090	6070	770(14.52)	580(8.9)
T_7(N.P.K+Zn+B)	7600	6100	800(15.09)	1090(16.74)
T_8(N.P.K+S+Zn+B)	7630	6400	1100(20.75)	1120(17.20)

4.5.1 Physicochemical properties of experimental soil in pot experiment (wet season, 2018)

The Physicochemical properties of experiment soil are described in Table (4.20). Unlike the previous sites, the soil in this experiment was moderately alkaline, and soil texture was sandy clay soil. The content of organic carbon was very low and total nitrogen, and available phosphorus were at a low level. Although available K and Ca were sufficient, Mg level was low. Regarding the tested nutrients, available S and Zn were low, but B maintained at medium level.

4.5.2 Plant growth characters in pot experiment (wet season, 2018)

Crop establishment is required balanced nutrition not only macronutrient but also micronutrients. Applying only macronutrients are not sufficient for crop growth. It was shown clearly in the picture (Plate 25-28). This picture showed that the effect of sulphur is the most prominent than the other two nutrients (Zn and B) and followed by that of zinc. Enhancement of sulphur in increasing tiller, number of spikelets were found by Samaraweera, et al (2009). The effect of boron on crop establishment was not found. It may be its specific effect on the reproductive part such pollen development.

In two nutrient combination treatment, sulphur plus zinc is the most vigorous and Zn plus B is in minimal. Similar statement was revealed by Samaraweera, Waikhom & Singh (2009). Author stated that sulphur and zinc are an essential nutrient for rice and deficiencies of these elements are also more common.

The most vigorous crop growth characters among the treatments plant height, tillering capacity, panicle length and total dry mater were shown in T_8 (Figures 4.14, 4.15, 4.16 and 4.17). The plant height data were collected in two-week interval started from 14 days after transplanting. Plant height was highest in T_8 and it also give the maximum total tiller among the treatments (Figure 4.14 and 4.15).

4.5.2.1 Panicle length (cm)

The panicle length with treatment were found significantly different. The highest was obtained by T_8 and T_6. Complete treatment can higher 11% in panicle length than T_1 too (Table 4.21 and Figure 4.16).

4.5.2.2 Total dry matter (gram pot^{-1})

The highest dry matter was found in T_8. It was grater 40% than T_1. The next higher treated pots were T_6 follow by T_2 and T_5 (Table 4.21 and Figure 4.17).

Table 4.20 Physicochemical properties of pot experimental soil (wet season, 2018)

Particular		Rating
Moisture%	2.96	
pH	8.14	Moderately alkaline
Texture	46:8:46	Sandy clay
Organic Carbon(%)	0.16	Very Low
Total N (%)	0.18	low
Available P (mg kg^{-1})	13.24	low
Available K (mg kg^{-1})	170.27	medium
Ca(meq100g $^{-1}$)	26.8	high
Mg (meq100g^{-1})	1.37	Low
Water-soluble SO_4 (meq100g^{-1})	0.64	Low
Available Zn (mg kg^{-1})	1.73	Low
Extractable B (mg kg^{-1})	1.8	medium

4.5.3 Yield and yield component in pot Experiment (wet season, 2018)

4.5.3.1 Number of effective tiller hill^{-1} among treatments

Effective tiller is a major component of grain yield. In this experiment, the effect of treatments on the effective tiller was found with significant level. Addition of complete treatment can give the highest level and adding nutrient except Boron alone can provide higher figure than T_1 on effective tiller number (Table 4.21 and Figure 4.18).

4.5.3.2 Number of spikelets panicle^{-1}

There were significantly different among the treatments. However, the addition of minor nutrients was not greater over control (T_1). It might be due to the effect of lesser tiller number in T_1 having too low effective tiller and less in number of panicle in a plant and thus sharing of the absorbed nutrients to panicle for developing spikelet is higher in pot which received only macronutrients. Therefore, number of spikelet by the plant fruitfully was found in T_1 (Table 4.21, Figure 4.19).

4.5.3.3 Filled-grain percent

In this experiment, effect of adding minor nutrients was not found and the highest filled grain percent was found at T_1. It may be due to the effect of nutrient sharing for each spikelet in plant. The pot with lesser number of tiller received more nutrient share for each spikelet and tiller than other treated pots which have greater tiller. However, the pot received all nutrients showed the highest filled grain percent as much as T_1 did (Table 4.21 and Figure 4.20).

4.5.3.4 Thousand grain weight (g)

Most of the figure and most of the research showed that the grain weight is determined only by varietal differences. But in this experiment, the differences with treatment was found significantly. The lowest grain weight was observed in T_3 treatment showing Zn adding might hurt grain weight. Because of less in total spikelet, grain weight of T_1 showed the high figure. However, a combination of other nutrients sulphur and boron having a greater effect on grain weight. The result found by Lordkaew, Konsaeng, Jongjaidee, Dell, Rerkasem, and Jamjod (2013) was that boron application at flowering stage increased grain weight and yield .In this study it was observed that the grain weight demonstrated by S+B was statistically higher than control (Table 4.21 and Figure 4.21).

Table 4.21 Mean comparison of crop performance, yield and yield component in pot experiment (wet season, 2018)

Treatment	Panicle length (cm)	TDM g pot^{-1}	Effective Tiller $hill^{-1}$	Spikelet $panicle^{-1}$	Filled-grain%	1000-grain wt.(g)	Grain Yield (t ha^{-1})
T_1(NPK)	20.6de	15.67 e	7c	104.87a	85.91a	23.72bc	2.79d
T_2(NPK+)	21.93bc	21.56 abc	11.67ab	100.7a	73.36d	23.66bc	3.90b
T_3(NPK+Zn)	21.2cd	19.19 cd	12ab	97.33ab	73.03d	19.97e	3.25c
T_4(NPK+B)	21cde	16.73 de	11b	85.49cd	84.65a	21.46d	3.26c
T_5(NPK+S+Zn)	19.86e	20.97 abc	12.67a	78.89d	78.76bc	22.5cd	3.32c
T_6(NPK+S+B)	23.43a	21.83 ab	10.67b	103.7a	74.92cd	25.48a	3.94b
T_7(NPK+Zn+B)	21.3cd	19.33 bc	12ab	89.5bc	81.84ab	24.2b	4.08b
T_8(NPK+S+Zn+B)	23.02ab	22.10 a	13a	98.32ab	83.1ab	24.78ab	5.04a
$LSD_{0.05}$	1.17	2.5	1.42	9.10	5.14	1.223	1.712
Pr > F	**	**	**	**	**	**	**
C.V%	3.11	7.28	7.23	5.48	3.69	3.01	5.08

ns = not significant, *= significant at 5% level, **= highly significant at 1% level

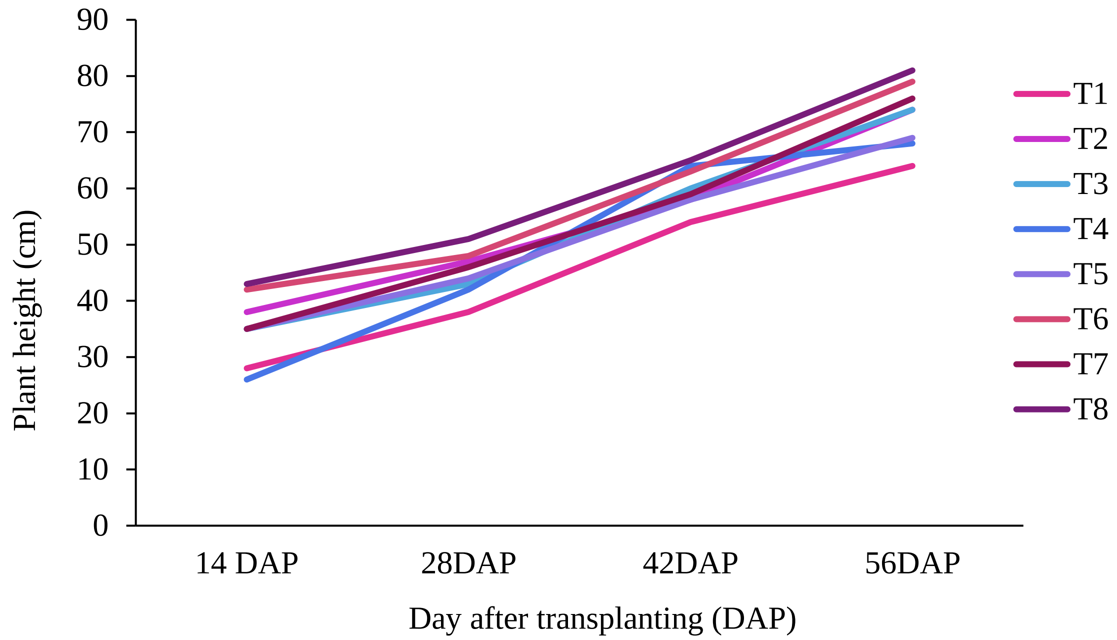


Figure 4.14 **Plant height (cm) with time among the treatments in pot experiment (wet season, 2018)**

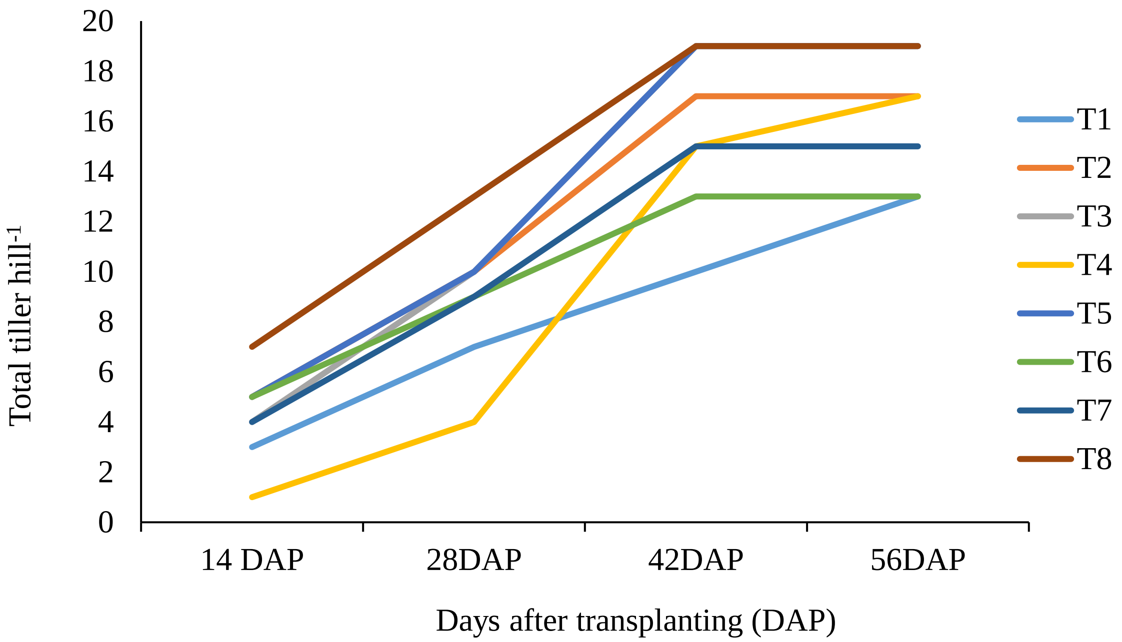


Figure 4.15 **Number of total tiller hill^{-1} among the treatments in pot experiment (wet season, 2018)**

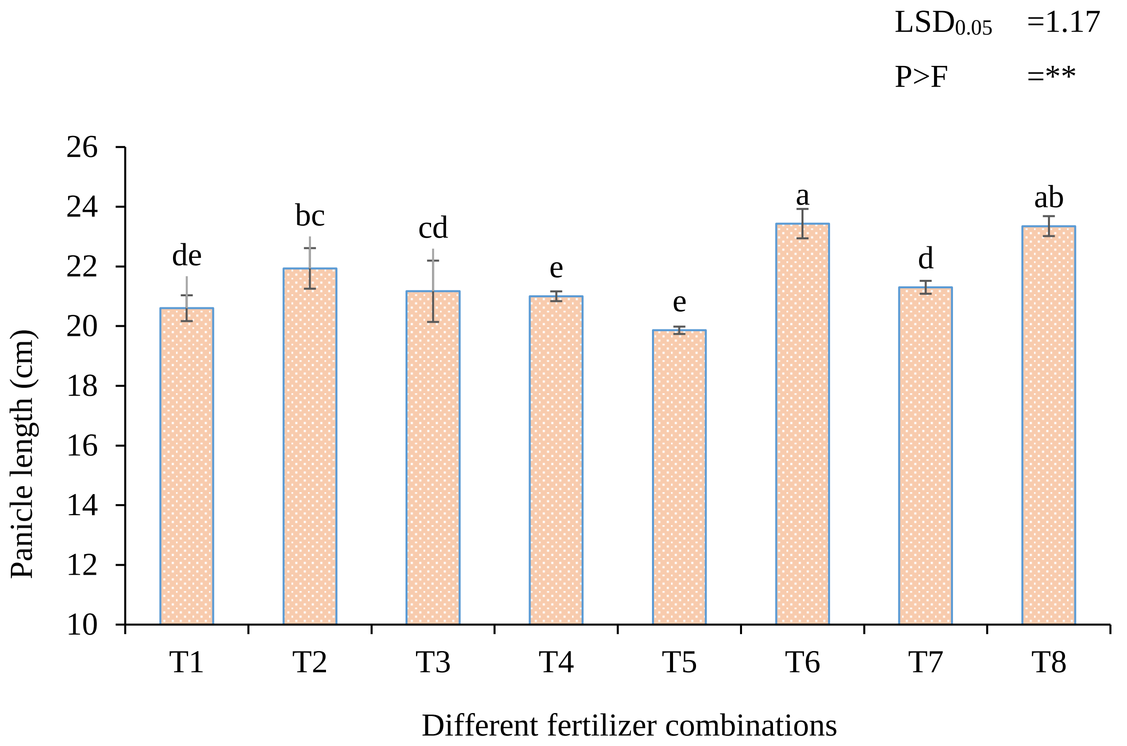


Figure 4.16 Mean comparison of panicle length (cm) among the treatments in pot experiment (wet season, 2018)

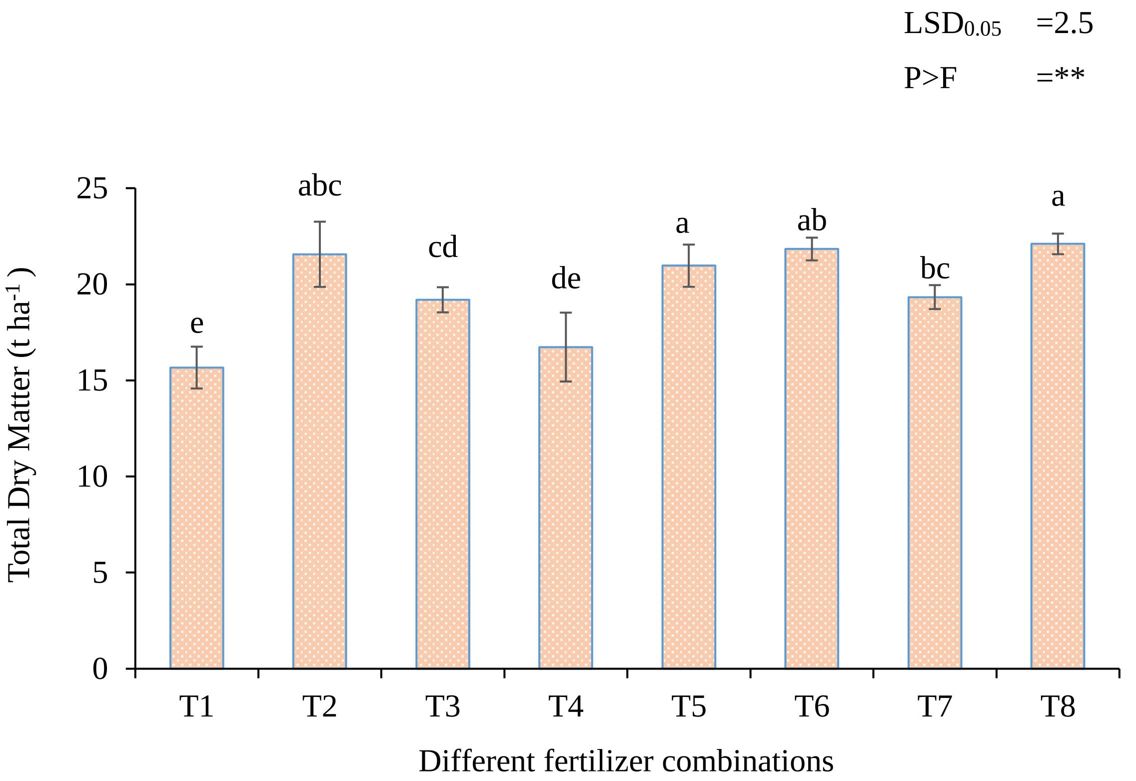


Figure 4.17 Mean comparison of total dry matter pot^{-1} among the treatments in the pot experiment (wet season, 2018)

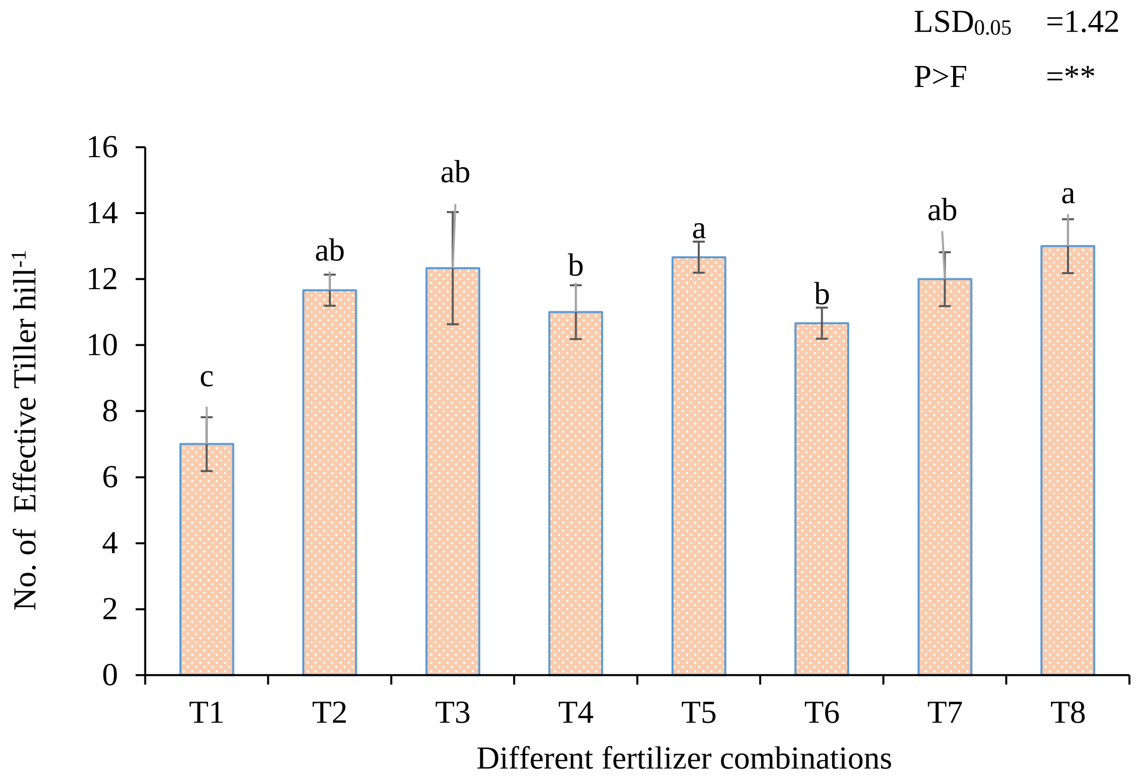


Figure 4.18 Mean comparison of number of effective tiller among the treatments in the pot experiment (wet season, 2018)

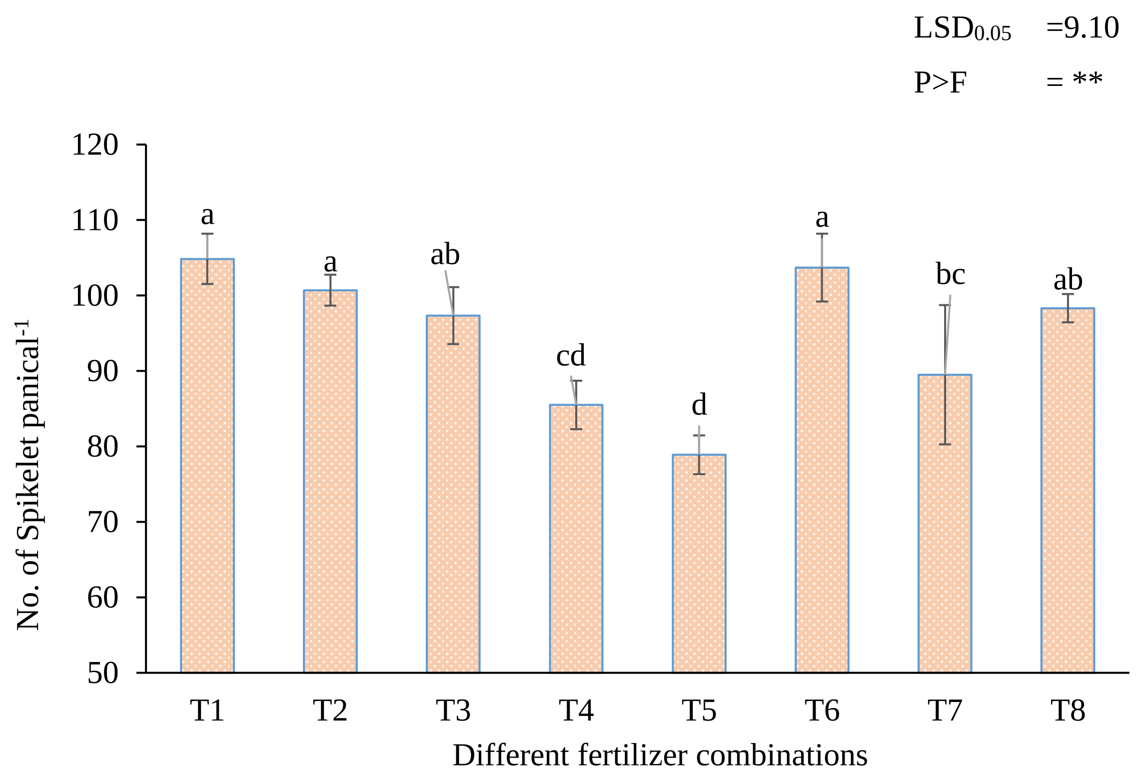


Figure 4.19 Mean comparison of number of spikelet panicle^{-1} among the treatments in the pot experiment (wet season, 2018)

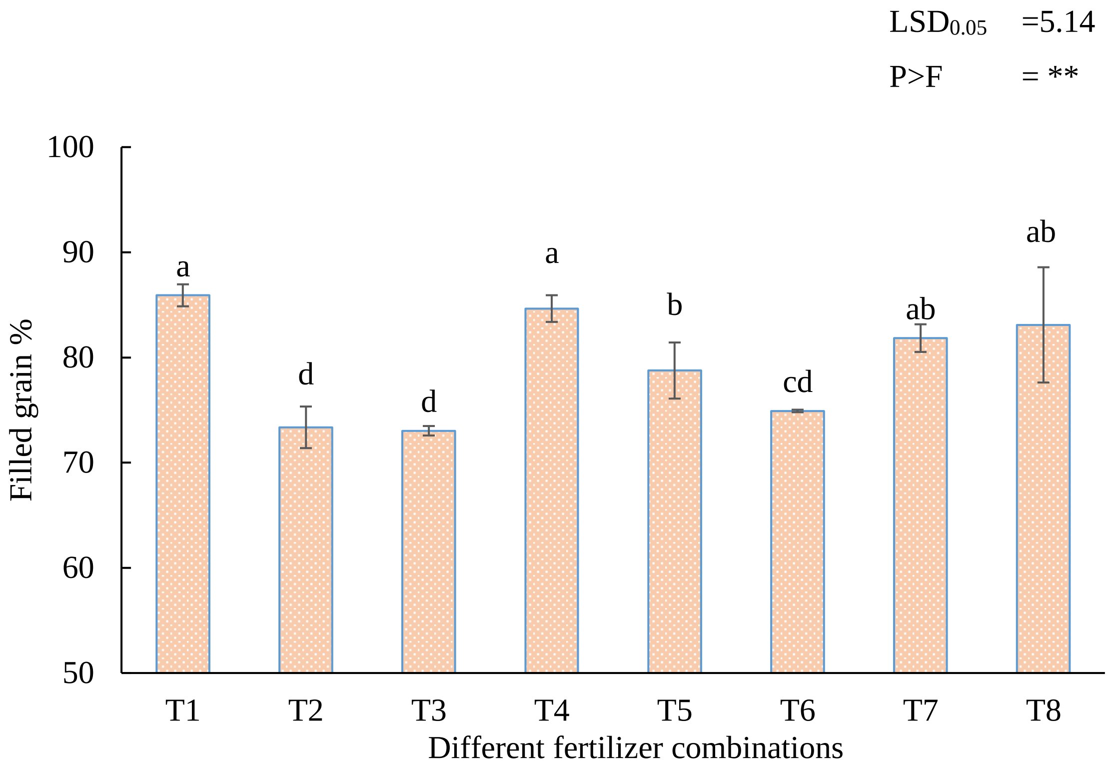


Figure 4.20 Mean comparison of filled- grain percent among the treatments in the pot experiment (wet season, 2018)

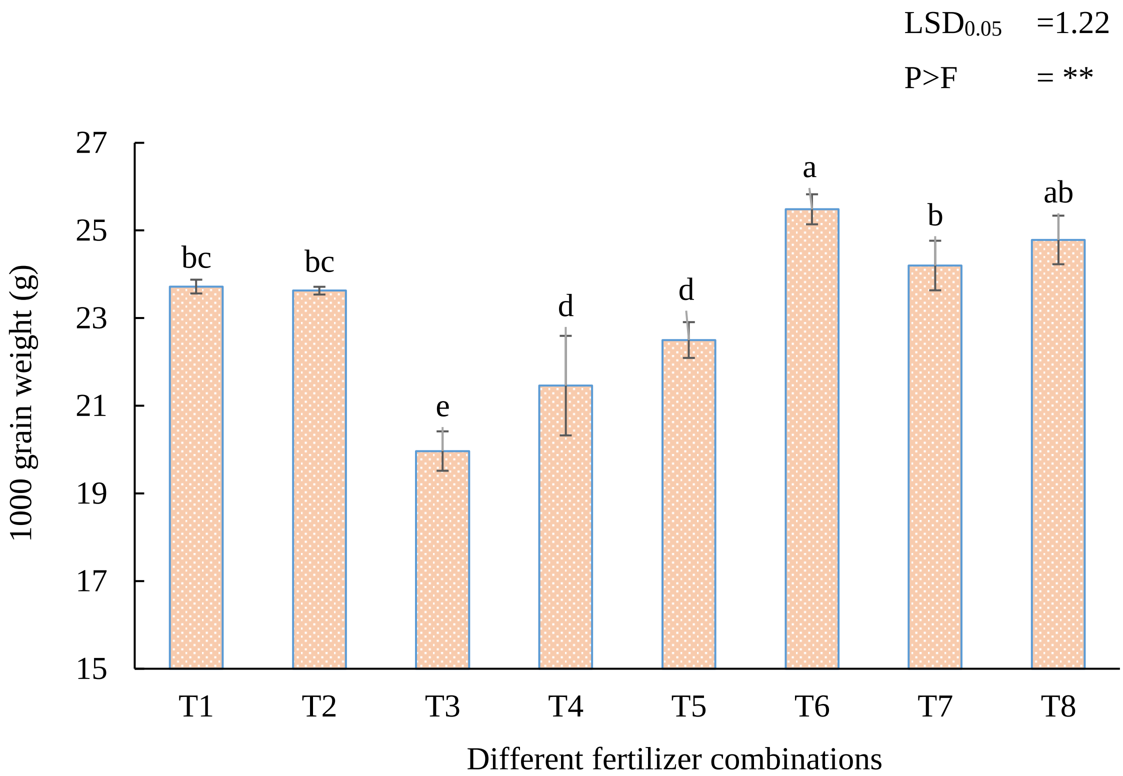


Figure 4.21 Mean comparison of thousand grain weight (g) among the treatments in the pot experiment (wet season, 2018)

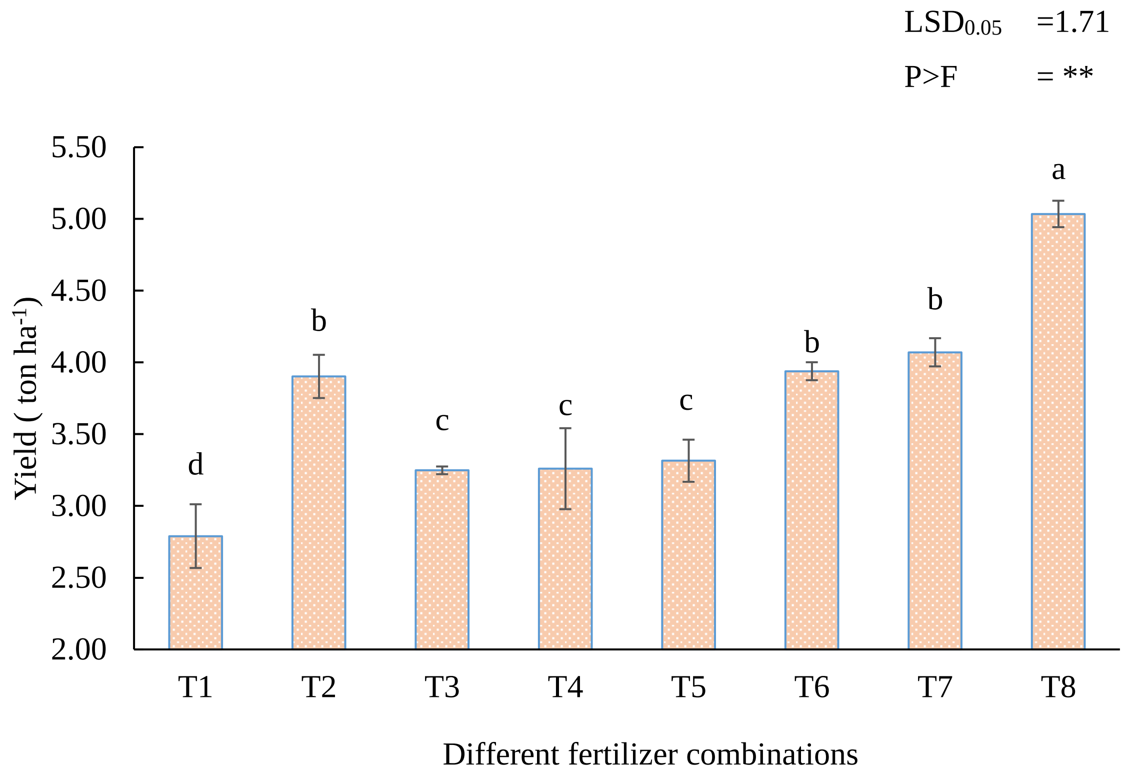


Figure 4.22 Mean comparison of grain yield ton ha^{-1} among the treatments in the pot experiment (wet season, 2018)

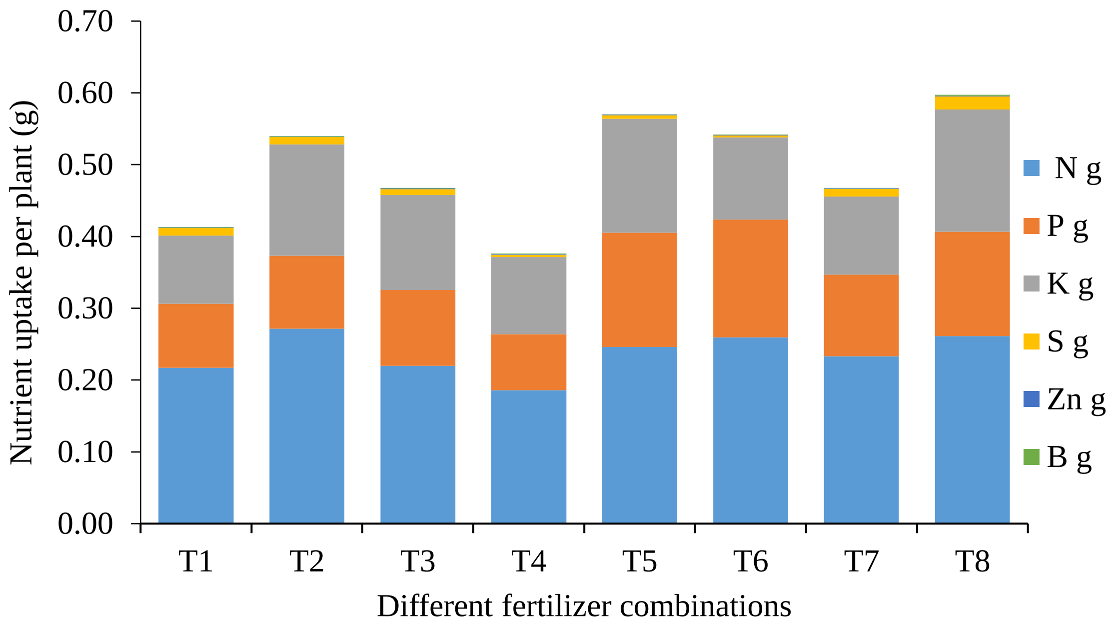


Figure 4.23 Nutrient uptake by plant among the treatments in the Pot experiment (wet season, 2018)

4.5.3.5 Yield per unit area (ton ha^{-1})

The most important parameter of the experiment is yield per unit area. The main target of crop production is yield, and every technology tested in experiment aim for increasing yield and the next one followed by the quality of the product. In this experiment, the highest yield was found in T_8, all complete treatment and the T_1 (only N, P, K) provided the lowest yield. Yield increased nearly double by application of full treatment (NPK+S+Zn+B). It showed the requirement of Sulphur and micronutrients is great in this soil. The second highest was found in T_7, followed by T_6 and T_2. It was described in Table (4.21) and Figure (4.22). An additional plot of S can give 39.92% yield increased, 16.46% by Zn and 16.87% by B. This study showed the importance of Zn and B application.

4.5.4 Fertilizer use efficiency in pot experiment (wet season, 2018)

4.5.4.1 Agronomic efficiency (AE)

Fertilizer use efficiency (Agronomic Efficiency) of adding minor nutrients are described in Table (4.22). Fertilizer Use Efficiency (A.E) in this experiment was highest in T_7, and followed by T_4 boron treatment because it might be small amount applied in an experiment. However, the crop response to add the Zn and B in the soil is expected.

4.5.4.2 Partial factor productivity (PFP)

Partial factor productivity of this experiment can be found in followed (Table 4.23). In partial factor productivity of nutrients, the highest was found in T_4 and followed by T_3 and T_7. From this finding it can be stated the effectiveness of Zn and B were found clearly. Also, the highest total added nutrients PFP was found in T_8 (S+ Zn+ B) together with major nutrients (N, P, K). Moreover, PFP of major nutrients also increased 14.8 kg per kg by T_8 (adding tested nutrients, + S+Zn+B) over NPK alone.

4.5.4.3 Nutrient harvest index (NHI)

Individual effect of sulphur, zinc and boron on the harvest index of N, P and Zn are shown in Table (5.5) The harvest index of nitrogen, phosphorus and sulphur might be increased by adding all three nutrients. Frageria (2009) stated that the average SHI is 48 in crops while it is about 43 in upland rice. The harvest index of Zn varied depend on Zn level crop species and crop management practices. Average values were observed 0.60 and 0.28 by Fageria and Baligar, (2005b). The study showed the highest SHI was at T_8, that of Zn HI was at T_2 and maximum BHI was found in T_1 accounting 88, 58 and 59 respectively. The harvest index of boron (BHI) in upland rice is 36 (less than 50%) while Zn HI was found 50% at harvest (Fageria 2009). In completed treatment, the harvest index of nutrients were found 62.48 in N, 62.3 in P, 49.66 in K and 88.6, 60.77 and 40.98 in S, Zn and B respectively. This finding of experiment is greater than that of Fageria's finding. The everage figures of the nutrient HI in experiment were within the frame of Fageria.

4.5.5 Nutrient accumulation in plant in pot experiment (wet season, 2018)

Nutrient accumulation with treatments was shown in Appendix (12). As the study results, nutrient accumulation with treatments varied; high in the pot with macronutrient plus micronutrients, and the lowest was found in T_1 (only major nutrients apply). The lowest level of nutrients (N, P, and K) were found either in grain and straw at T_1. Mostly major nutrients uptake was highest in T_8, and the lowest was found in T_1. This figure showed the uptake of the major nutrient could increase by adding other macronutrients and micronutrients S, Zn, and B (Figure 4.23). This result agreed with the finding of Dash, et al., (2015).

The content of nutrients (N and P) were higher in grain, and K was higher in straw in treatment 2, 3, 5, and 8. A similar result was found by Yoshida, (1981). Although Fageria (2009) stated that content of sulphur is higher in straw than grain like potassium, in contrast, the S content was found variation with treatments in this experiment. While Zn content was higher in grain than straw B was found more in straw in all treatments. Nutrient taken up by the plant is varied based on the differences of the dry matter and grain yield among the treatments. Nutrient uptake by plant with treatments was described in Figure (4.23). T_2 and T_8 have highest in nitrogen uptake, and all treatments except T_4 were found greater in P than T_1. K uptake by all treatments were also greater than T_1, and the highest was found in T_8. T_1 can be seen as the least uptake in K among treatments. However, the micronutrients uptake by treatments were found not too much clear. Fageria (2009) stated that macronutrient accumulation was much higher than that of micronutrient in cereal as well as legume crops. Probably nutrient uptake, especially micronutrients might be based on many factors such as soil, weather, type and applied dose of those nutrients. However, it can be clearly seen the uptake of nutrients are greater in the pot receiving micronutrient together with macronutrients and it would give the higher yield for production and improved fertilizer use efficiency and thus the less requirement of nutrients for the same yield (1 ton) (Table 4.26).

Nitrogen uptake also enhanced with Zn and S fertilization in experiment. Such a synergistic relationship between N and S has been reported by Saha and Datta (1991).

The greater dose of Zn promoted the better uptake of Sulphur; the however increasing level of S reduced the Zn uptake in rice crop. Which is to be critically evaluated in the further investigation to find out the physiological mechanism of S and Zn in the life cycle of hybrid rice (Veerendra & Parihar, 2012). Increasing major nutrient uptake can cause a higher yield with improved nutrient use efficiency. Fageria (2009) stated that 215 g Zn and 60 g B would be removed for 5 ton ha^{-1} yield. This author approved the improved N uptake by Zn application in rice.

Tariq & Mott (2007) indicated that B increase N uptake but high B induce Zn uptake less. However. Baktear, et al. (2001) noted the recovery efficiency of B is only 5-10 in field crop, and sufficient level of 200g was reported by Shorrocks, (1997). As observing the result, the highest uptake of nutrients (N, P, K, S, Zn, and B) were found by the application of combined micronutrients along with major NPK (Table 4.25). A similar result was obtained by Baktear et al., (2001). This study showed the nutrient requirement for the same yield (1 Ton) based on applied nutrients through treatments in Table (4.26). By application of combined nutrients (macronutrient +micronutrient) can save 33 percent in N, about 10 in P and 0.89% in K. Present study showed the major nutrient application could be reduced by applying minor nutrient together with major nutrients. Overview of nutrient saving is 20% in major and 0.04% in a minor by the combined application.

4.5.6 Soil nutrient after harvesting in pot experiment (wet season, 2018)

The initial soil fertility and remaining status of nutrients after harvest among the treatments are shown in Appendix (10). The tested nutrients except sulphur remaining in the soil are stable by applying nutrients that required by plants. The less amount of sulphur in remaining in the soil might be the plant used much and adding amount was insufficient or losses during the crop season. On the other hand, it might be due to the dynamic nature of S in the soil. Residual nutrients after harvest are shown in Appendix (10). The significant differences among treatments were found in P, K and S in this experiment. The residual N and B were found in 0.06 and 0.09 level in Probability. The residual nutrient of T_8 was not found in high level except at the level of boron because a substantial amount of nutrients might be used by plant for higher yield. Fageria (2009) stated that the residual effect of B fertilizers depends on crop yield and clay content of the soil e.g. in clay soils (> 30% clay content) and residual effect of adequate rate of B (2 to 4 kg B ha^{-1}) may persist for three to four subsequently grown crops.

Table 4.22 Agronomic efficiency (AE) in pot experiment (wet season, 2018)

Treatments	Yield (kg ha^{-1})	Differences (kg ha^{-1})	Applied nutrient (kg ha^{-1})	Agronomic Efficiency
T_1 (N.P.K)	2793	-	-	-
T_2 (N.P.K + S)	3907	1114	30	37.13
T_3 (N.P.K +Zn)	3252	459	5	91.80
T_4 (N.P.K + B)	3264	471	3	157.00
T_5(N.P.K+ +Zn)	3319	526	35	15.03
T_6(N.P.K+ S+ B)	3944	1151	33	34.88
T_7(N.P.K+Zn+B)	4076	1283	8	160.38
T_8(N.P.K+S+Zn+B)	5041	2248	38	59.16

Table 4.23 Partial factor productivity (PFP) in pot experiment (wet season, 2018)

Treatments	Yield (kg ha^{-1})	Major Nutrient PFP	Tested Nutrient PFP	Total Nutrient PFP
T_1 (N.P.K)	27.92	18.37	0.00	18.37
T_2 (N.P.K + S)	39.07	25.71	130.24	21.47
T_3 (N.P.K +Zn)	32.52	21.40	650.45	20.71
T_4 (N.P.K + B)	32.64	21.47	1087.91	21.06
T_5 (N.P.K + S+Zn)	33.19	21.84	94.84	17.75
T_6 (N.P.K + S+ B)	39.43	25.95	119.51	21.32
T_7 (N.P.K +Zn+ B)	40.76	26.81	509.48	25.47
T_8 (N.P.K S+Zn+B)	50.41	33.17	132.66	26.53

Table 4.24 Nutrients harvest index (NHI) in pot experiment (wet season, 2018)

Treatment	NHI (%)	PHI (%)	KHI (%)	SHI (%)	ZnHI (%)	BHI (%)
T_1 (N.P.K)	57.15	55.93	62.46	42.14	61.48	59.32
T_2 (N.P.K + S)	63.16	71.43	46.41	39.59	68.58	43.90
T_3 (N.P.K +Zn)	66.64	61.02	47.25	33.87	66.26	22.03
T_4 (N.P.K + B)	75.02	76.09	58.29	16.43	62.04	45.45
T_5 (N.P.K + S+Zn)	57.90	45.78	41.93	36.80	53.12	48.65
T_6 (N.P.K + S+ B)	66.64	42.86	62.94	14.17	49.76	44.00
T_7 (N.P.K +Zn+ B)	64.70	59.13	62.94	72.00	59.66	33.33
T_8 (N.P.K +S+Zn+B)	62.48	62.30	49.66	88.62	60.77	40.98

Table 4.25 Nutrients uptake kg ha^{-1} in pot experiment (wet season, 2018)

Treatment	Yield ton ha^{-1}	N	P	K	S	Zn	B
T_1 (N.P.K)	2.79	42.90	7.68	15.67	2.05	0.12	0.18
T_2 (N.P.K + S)	3.91	53.62	8.76	25.58	2.01	0.12	0.17
T_3 (N.P.K +Zn)	3.25	43.42	9.13	21.83	1.58	0.12	0.22
T_4 (N.P.K + B)	3.26	36.77	6.73	17.63	0.69	0.12	0.22
T_5 (N.P.K + S+Zn)	3.32	48.59	13.73	26.18	0.94	0.16	0.14
T_6 (N.P.K + S+ B)	3.94	51.26	14.15	18.89	0.54	0.18	0.11
T_7 (N.P.K (+Zn+ B)	4.08	46.09	9.82	17.88	2.10	0.15	0.11
T_8 (N.P.K +S+Zn+B)	5.04	51.63	12.52	28.07	3.60	0.17	0.27

Table 4.26 Nutrients absorbed by plant for 1-ton Grain Yield in Pot experiment (wet season, 2018)

Treatments	N(kg)	P(kg)	K(kg)	S(kg)	Zn(kg)	B(kg)
T_1 (N.P.K)	15.36	2.75	5.62	0.73	0.04	0.06
T_2 (N.P.K + S)	13.72	2.25	6.55	0.52	0.03	0.04
T_3 (N.P.K +Zn)	13.35	2.81	6.72	0.49	0.04	0.07
T_4 (N.P.K + B)	11.27	2.07	5.40	0.21	0.04	0.07
T_5 (N.P.K + S+ Zn)	14.64	4.14	7.89	0.28	0.05	0.04
T_6 (N.P.K + S+ B)	13.00	3.59	4.79	0.14	0.04	0.03
T_7 (N.P.K +Zn+ B)	11.31	2.41	4.38	0.52	0.04	0.03
T_8 (N.P.K +S+ Zn+ B)	10.24	2.48	5.57	0.71	0.03	0.05
Decrease %	33.27	9.8	0.89	2.74	25.00	16.66

Plate 3-6 Photo of assessment survey and soil sampling (2017)

Plate 7-11 Photo of pot experiment (dry season, 2017)

Plate12-16 Photo of field experiment in Pobbathiri (wet season, 2017)

Plate17-21 Photo of field experiment in Zeyarthiri (wet season, 2017)

Plate22-24 Photo of pot experiment (wet season, 2018)

Plate 25 Crop performance in 14 days after transplanting

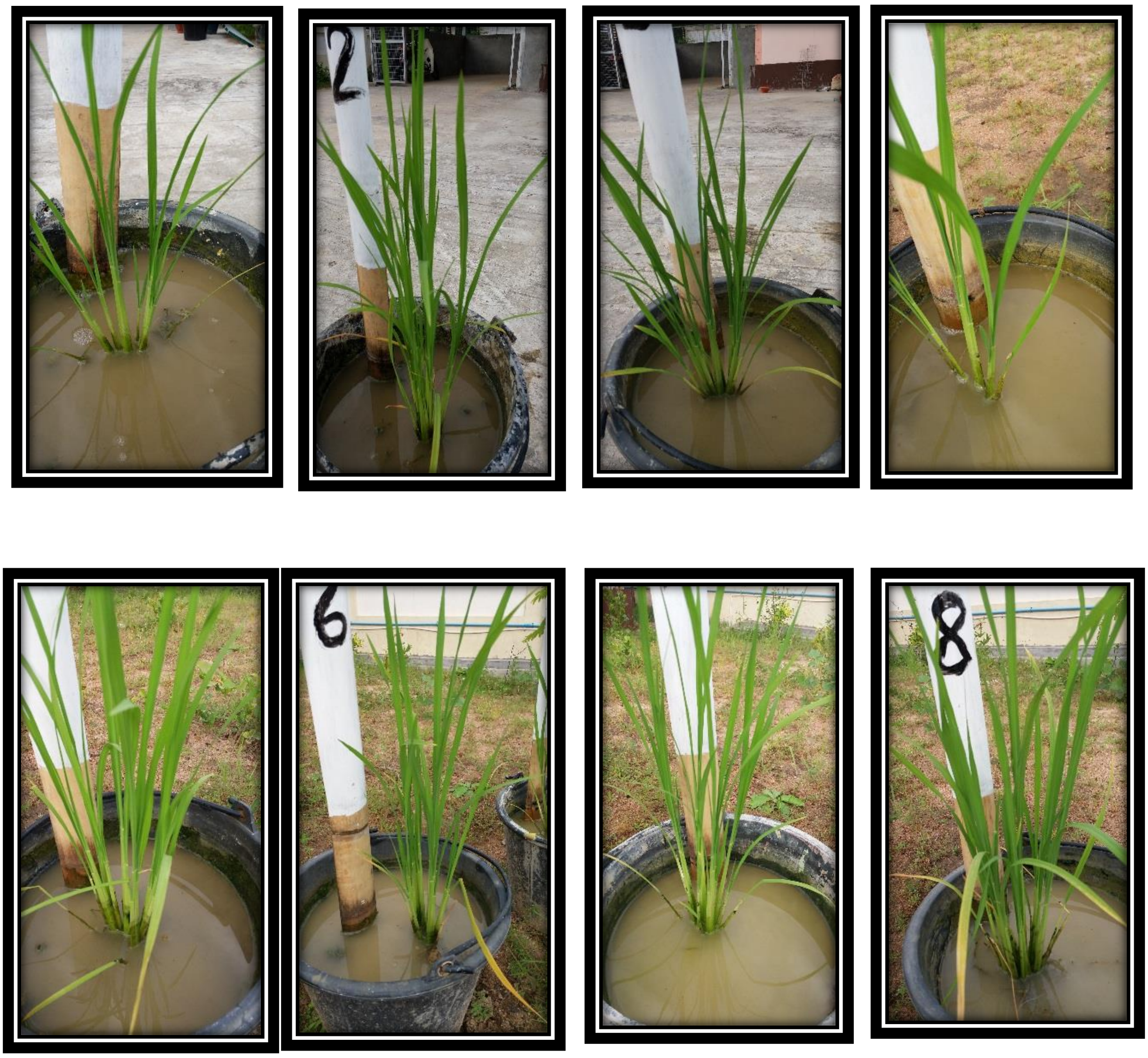


Plate 26 Crop performance in 28 days after transplanting

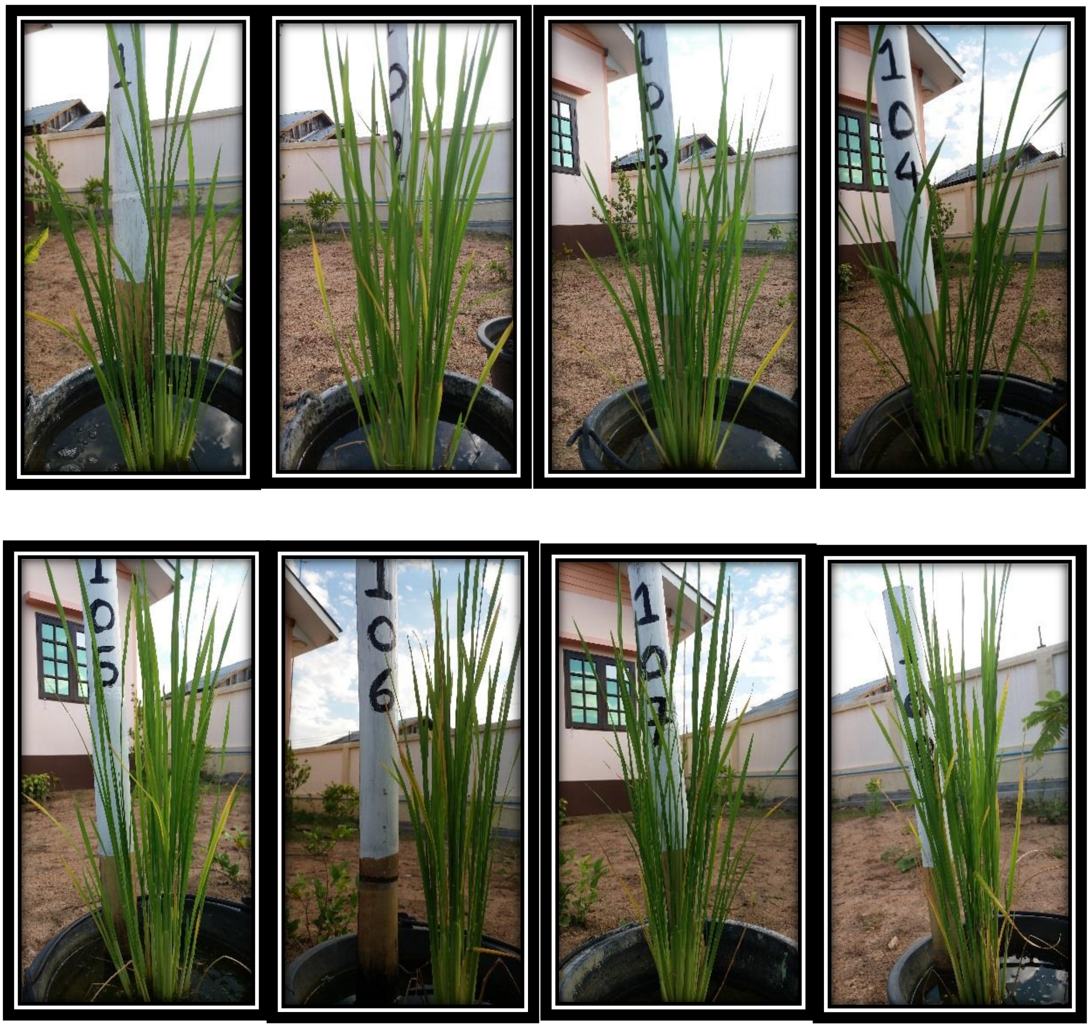


Plate 27 Crop performance in 42 days after transplanting

Plate 28 Crop performance in 56 days after transplanting

CHAPTER V
GENERAL DISCUSSION AND CONCLUSIONS

5.1 Balanced Fertilizer Application Effect on Grain Yield

Because of the applying high cropping intensity and inadequate amount of fertilizers, the study area is facing with fertility depletion. This exhausted fertility might be the lack of matching the nutrient replenishment and removal from soil by crops in fact. Ashamed and Elias (1986) has been stated that the fertility depletion and unbalanced nutrient in the soil might be resulting from without matching in fertilizer input and output as Cropping Intensity (CI) increases. The study demonstrated that the most of the macronutrient and micronutrients are deficient in rice land in Naypyitaw, but it has a sufficient level of K. Although some farmers adopted pulses growing in their cropping system, the nutrient provided by pulses is not enough for the next crop requirement of nutrients because they did not use any fertilizer in pulses growing except foliar spraying. And thus, paddy land in the study area showed fertility demand in both macronutrient and micronutrient. It does not depend on the cropping system conclusively but also fertility management and indigenous soil fertility level in rice land. Also, some of the major nutrients may inhibit yet minor nutrient availability in rice land. For example, the high potassium level may retard minor nutrient boron availability from the soil. A similar statement was shown by Gupta (1979). However beneficial effect of K on Zn uptake in a rice field is approved by Dibb and Thompsom, (1985). Application of secondary element is not the only aim for increasing yield but also for increasing major nutrient efficiency. It has been approved that insufficient supply of secondary element can reduce the major nutrient efficiency by Arihara & Srinivasan (2001).

The first study pointed out the needs of macronutrients and micronutrients in rice land and has been evaluated the possible causes of this nutrient deficiencies were recorded. After the study of fertility status in Naypyitaw area, pot experiment was conducted to evaluate the effect of sulphur, zinc and boron in rice cultivation with the soils from two Townships (Pobbathiri and Zeyarthiri) during dry season of 2017. The fertility of Zeyarthiri soil is better in P and Zn content than Pobbathiri field while organic carbon, total N, available K is more abundant in the Pobbathiri soil. Based on the soil indigenous level, the grain yield and spikelet panicle^{-1} is greater in Zeyarthiri soil. Due to the effect of organic carbon, total N, and available K, number of tiller hill^{-1} and filled grain percent is higher than in Pobbathiri soil. The experimental result showed that filled grain percent and grain yield among the treatments were significantly different.

By the addition of S, Zn and B resulted the highest yield in both soils. S and Zn alone cannot provide the higher yield in Pobbathiri soil but its effect can be seen clearly in Zeyarthiri soil. The result in the experiment recorded that the effect of B was dominant in both soils among the three nutrients applied. In two combination treatments, Zn + B can give the highest yield and S + Zn combination is more response than S + B combination treatment. However, the treatment containing S, Zn and B together with N, P, K produced highest grain yield. It increased 0.865 ton ha^{-1}yield over T_1. (17.3 basket ac^{-1}). This study pointed out the rice field required not only macronutrients but also micronutrients.

During wet season of 2017, experiments on farmer's field were conducted in above Townships**.** The fertility status of N, P, K and S were higher in Zeyarthiri soil but boron. Soil pH, organic carbon, available Ca, Mg, and Zn were nearly the same in two experiment sites. According to experimental result of Pobbathiri field addition of complete nutrient (T_8) gave the highest value of yield, and the lowest was found in (T_1). Although it is not significantly different in Pobbathiri experimental soil, it increased 1.1 ton ha^{-1} and the increase percent was twenty-one. The treatment of T_2, application of sulphur can increase yield at 6.98 percent to control. Likewise, the yield of T_3, T_4, T_5, T_6, T_7, and T_8 are higher 15.66, 16.98, 16.98, 14.53, 15.09, and 20.56 than control in percent. The highest yield was found in T_8, and the lowest was in T_1. T_8 is greater 25% in effective tiller, 17.13% in spikelets per panicle, 9.4% in filled- grain and 20.75% in grain yield over $T_{1.}$ Overall treatments, T_8 gave the highest yield increasing Twenty percent over control. Similar result was found by (Dash et al., 2015).

In Zeyarthiri experiment, the treatment containing, S, Zn and B together with NPK (T_8) produced highest grain yield (7.63 t ha^{-1}), and the lowest yield (6.51 t ha^{-1}) was found in T_1. Among the treatments, T_7 gave the approximately equal to the yield of T_8 hence, the importance of S is lesser than that of the rest two elements. However, an additional plot of sulphur produced 10.9 percent yield increased to control. In other treatments fromT_3 to$T_{8,}$ the percent increase in grain yield is 12.29, 13.52, 11.98, 8.90, 16.74, and 17.20 over T_1. Although crop performance with treatment is not different, filled grain percent and yield were different with treatments. Filled grain % was highly significant and highest were found in T_7 and T_8. The grain yield was highest in T_8 followed by T_7 and lowest was in T_1. T_8 is greater 0.70% in E tiller, 3.33% in spikelets panicle $^{-1}$, 19.08% in filled grain, 4.63% in grain wt. and 17.20% in yield over T_1. The yield of overall treatments in Zeyarthiri experimental site has a greater than Pobbathiri. However, the yield trend with two experiments was nearly the same pattern (Figure 4.26). The response of added nutrients in rice was sigmoid shape in both experiments. The effect of Zn and B were more than individual S adding; however, by adding all nutrient series is the best. The second largest was found in T_7 (Zn+ B combination).

In 2018, pot experiment with Pobbathiri soil was conducted again to study either yield or nutrient uptake by plant. In this experiment, crop performance character with treatment was highly significant among treatments. The panicle length, total tiller, and total dry matter were found significantly among treatments. In yield components, there were differences in number of effective tiller, TDM, and economic yield by treatments. The length of panicle in T_8 was greater 11.75 % over T_1. Total dry matter of T_8 was found greater in 40 percent over T_1. In yield contributing data, the highest filled-grain percent were obtained by T_7, T_8, T_1 and T_4. The lowest was found in T_2 and T_3. However, T_8 was significantly superior over all treatments in this experiment. Yield increased nearly double by application of full treatment (NPK+S+Zn+B). It showed the requirement of sulphur and micronutrients is great in this soil. The second highest was found in $T_{7,}$ followed by T_6 and T_2. It was shown in Table (4.21) and Figure (4.35). The addition of complete nutrients (T_8) is greater 85% in E tiller, 4.46% in grain weight and 80.52% in yield over T_1. An additional plot of S demonstrated 39.92% yield increased, 16.46% by Zn and 16.87% by B.

In view of yield in all experiments, response of nutrient was 6-40% by S, 2-16% by Zn and 4-17% by B based on soil and all combined nutrients increased up to 8 to 80.5 percent in the experiment. The finding of Dash et al. (2015) was also the decrease yield at 8 percent by the absence of S, Zn, and B. Boron plays a vital role in grain sterility for getting high yield of rice. The effect of B on, rice yield and yield attributing parameter has been approved by Sarwar et al. (2016), recorded the yield increased by boron at 10 bushel per acare and Baktear (2001) demonstrated the yield increased of B at 0.6 t ha^{-1} in rice.

In two combination treatments, Zn and B combination in the soil is expected due to the requirement of those elements were clarity than Sulphur. According to the research findings application of Sulphur, Zinc and Boron along with NPK is essential in this area to get maximum yield of rice.

5.2 Balanced Fertilizer Application Effect on Nutrient Use Efficiency

The efficiency of major nutrients are more prominent than other macronutrients and micronutrients. However, the study showed the high value of Agronomic Efficiency at micronutrients B and Zn + B combination treatments. Giordano and Mortvedt (1972) demonstrated that Zn is not effected on grain yield, however, it may indirectly effect on nutrient availability of major nutrient resulting in increased yield. The recovery efficiency of Zn is (5-10) percent, and (6-10) was observed by Brady (2002).

According to the study, it was found the efficiency of sulphur is 12.33-23.67 in acidic soil and 37.13 in sodic soil. Zn use efficiency has a broader range from 38 to 160 in acidic soil and 91 in sodic soil while the efficiency of B was 60-300. In two combination treatments, the highest FUE was obtained by Zn and B treated from 82.5-136. The highest yield was demonstrated by complete treatment (S+ Zn+ B), but FUE was found from 16.32 to 29.47 in acidic soil and 59.16 in sodic soil. Mookherjee and Mitra (2016) also reported the Zn and B become prominent in rice cultivation.

Nutrient availability depends on soil characteristic, especially pH. Most of the micronutrients are deficient in alkaline soil (Yoshida, 1981). Besides, there are synergic and antagonist effect within micronutrients. This complex feature of micronutrient determines not only on nutrient uptake but also on yield and yield contributing factors (White & Zasosaki, 1999). Mookherjee and Mitra (2016) also mentions that form part of N, P, K, sulphur, zinc, and boron play an important role in the agricultural crop production system.

5.3 Balanced Fertilizer Application Effect on Soil nutrients

The initial soil and post-harvest soil analytical data were mentioned in an Appendix (6) to (10). The result cannot express the increase of the nutrients level by treatments because the added nutrients were aimed for crop requirements only. However, based on the soil indigenous fertility level boron persist in the soil at higher level than initial. Generally, the micronutrients level in the treated plot maintained soil fertility level in growing land and leading to sustainability of the Agricultural productivity. The secondary element of S was more difficult to assess clearly since its organic form present in soil organic matter. Additionally, due to the dynamic nature of S in the soil, the soil test for S may have a limitation for making fertility evaluating.

5.4 Conclusion

Based on research finding, it can be concluded that fertilizer management, including balanced nutrition, is more important than which crop would be grown. While the cropping intensity is getting high, matching of nutrient input and output is crucial. Otherwise, nutrient-depleting may be faced with in the Agricultural sector, especially in rice cultivation since it is a major crop in the study area. Either macronutrient or micronutrient are equally important in order to meet balanced nutrition. Apart from NPK, sulphur, zinc, and boron are most important in rice cultivation in rice growing countries. Also in Myanmar, these nutrients are getting important since the use of HYV, including hybrid variety and adoption of high cropping intensity (C. I) in rice cultivation. Understanding the micronutrient effect on crop production is still insufficient due to the complex nature of those elements, their interaction, and contribution in the physiology of the plant. From the above finding, it can be concluded that, the effect of nutrients was mainly based on location since soil physical and chemical properties were varied with sites having different indigenous fertility level. Only the filled-grain percent and grain yield were significantly different among treatments. However, the highest yield can be obtained by all tested nutrients combination treatments. Although the interpretation of their effect is also still needed to be developed, nutrient uptake by the plant in complete treated is the highest and the lowest was found in the plot that received only macronutrients (N P K).With required macronutrients and micronutrients demonstrated a better yield than applying (N P K) only. It resulted in yield increased 10-80% based on soil. The results recorded the increased partial factor productivity (PFP) of major nutrients by adding required macronutrients and micronutrients. The nutrients accumulation in plant that received combined macronutrients and micronutrients greater than that in plant received only NPK (control) as yield increases. However, nutrient absorbed by plants in combined nutrients plot is lower than treatment of NPK only for the same yield. The result demonstrated that uptake of nutrient was decreased 30% in nitrogen and 10 percent in phosphorus for the same yield by addition of all combined nutrients (S+Zn+B). And thus, applying of macronutrients nitrogen and phosphorus can be saved, enhancing better N management with balanced fertilization. Furthermore, the harvest index of N, P and S increased by adding S, Zn and B together with NPK. This study revealed the effect and efficiency of sulphur, zinc and boron and the significance of adding these nutrients together with macronutrients (N, P, K) in soil for present and future aspect of rice cultivation in study areas of Naypyitaw.

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APPENDICES

Appendix 1 Survey Form

Assessment of fertility status on rice field

(a) Surveyor name---

(b) Respondent

- name
- age
- village tract
- Education

(c) agricultural land

- low land acre
- Up land acre
- Rice area
- No of field
- Sample field

(d) production status

- yield and variety used

Time	**Sowing area**	**variety**	**Total production**	**Yield acre^{-1}**
Previous year				
Last 2 year				
Last 3 year				
Last 4 year				
Last 5 year				

(e) Cropping pattern

Cropping pattern	**Recent year**	**Past 2 year**	**Past 3 year**	**Past 4 year**	**Past 5 year**
Rice- Rice					
Rice - pulses					
Rice - pulses- Rice					
Rice- other					

(f) In Put application

Type of Fertilizer	**Recent year**	**Past 2 year**	**Past 3 year**	**Past 4 year**	**Past 5 year**
Natural fertilizer					
Chemical fertilizer					
Bio fertilizer					

(g) Changes of soil properties during 5 years

Soil properties	**Change (IN/DE)**	**Not change**	**Not recognize**
Soil color			
Soil texture			
Fertility status			
yield			

(h) Remarked by farmers on his field

- Soil structure -----
- Topography -----
- Soil depth ------
- Soil fertility status ----

(i) Residue management -----

(j) Source of in put

(k) Economically feasibility

Appendix 2 Soil analytical result on farmers' fields (Pobbathiri Township)

Division - Naypyitaw

Township- Pobbathiri

Ser.	Farmer name	pH soil water 1:2.5	Organic carbon %	Total Nitrogen%	Water soluable SO_4 meq100g^{-1}	Available Zn mg kg^{-1}	Extractable B mg kg^{-1}	Exchangeable K meq100g^{-1}	Available nutrient P mg kg^{-1}	Available nutrient K_2O mg100g^{-1}
1	U Ko Naing	4.64	1.56	0.07	0.28	nd	0.38	0.22	3.24	10.49
2	U Ye Shwe	5.13	1.13	0.07	0.20	nd	0.37	0.23	11.79	10.89
3	U Sein Mg	5.51	2.56	0.13	0.24	nd	1.01	0.34	6.06	16.01
4	Daw Kyi San	5.60	1.00	0.07	0.20	nd	0.52	0.18	5.80	8.51
5	U Mg Soe	5.16	3.63	0.17	0.16	nd	1.12	0.40	3.91	18.83
6	U Thein	5.36	1.36	0.11	0.16	nd	0.52	0.23	4.83	10.86
7	Daw Kyi Than	5.32	2.14	0.11	0.24	nd	0.93	0.61	11.53	28.81
8	U Thein Tan	5.05	3.15	0.09	0.20	nd	0.53	0.33	5.8	15.44
9	Daw Mya	5.45	2.52	0.11	0.32	nd	1.59	0.44	18.01	20.77
10	U Hla U	5.16	2.40	0.11	0.24	nd	1.43	0.28	4.40	13.16
11	U Thet	6.38	0.89	0.07	0.40	nd	0.22	0.24	25.89	11.46
12	U Myo Win	5.58	2.36	0.09	0.68	nd	0.38	0.37	4.07	17.59

Appendix 3 Soil analytical result on farmers' fields (Zeyarthiri Township)

Division - Naypyitaw

Township- Zeyarthiri

Ser.	Farmer name	pH soil water 1:2.5	Organic carbon %	Total Nitrogen%	Water soluable SO_4 meq100g^{-1}	Available Zn mg kg^{-1}	Extractable B mg kg^{-1}	Exchangeable K meq100g^{-1}	Available nutrient P mg kg^{-1}	Available nutrient K_2O mg100g^{-1}
1	U Win	4.55	2.78	0.20	0.16	nd	1.66	0.29	7.64	13.67
2	U Min Naing	5.18	3.29	0.18	0.24	nd	1.49	0.28	4.07	13.19
3	U Thein Win	5.54	3.55	0.16	0.20	nd	1.35	0.52	46.76	24.62
4	U Ag Tun U	4.86	1.17	0.09	0.24	nd	1.16	0.33	15.81	15.67
5	U Ko Gyi	4.67	3.58	0.17	0.28	nd	1.23	0.66	5.87	31.17
6	U Ko Lay	4.60	3.68	0.14	0.20	nd	1.35	0.44	2.74	20.73
7	U Thein Myint	4.58	5.0	0.17	0.24	nd	1.28	0.60	5.71	28.30
8	Daw Phyu Khaine	4.76	2.74	0.14	0.28	nd	1.18	0.43	4.70	20.32
9	U Kyaw Lin	4.62	4.46	0.17	0.24	nd	1.01	0.63	4.94	29.55
10	U Myint Soe	4.28	2.24	0.11	0.28	nd	1.10	0.34	3.47	16.04

Appendix 4 Soil interpretation result on farmers' fields (Pobbathiri Township)

Farmer	Cropping Patten	FYM	pH	OC	Total N	Avail p	Avail K2O	Avail S	Avail Zn	Avail B
U ko Naine	2a(R,P)	L	SA	L	VL	L	M	L	nd	L
U ye shwe	2b(R,R)	N	SA	L	VL	L	M	L	nd	L
U sein Mg	3(R,P,R)	N	MA	M	L	L	M	L	nd	M
Dkyi sein	3(R,P,R)	L	MA	L	VL	L	M	L	nd	L
U Mg soe	3(R,P,R)	L	SA	M	L	L	M	L	nd	M
D Kyi than	2a(R,P)	N	MA	M	L	L	H	L	nd	L
U Thein Tan	2a(R,P)	M	SA	M	VL	L	M	L	nd	L
D Mya	3(R,P,R)	L	Ma	M	L	M	H	L	nd	M
U Hla U	2a(R,P)	M	SA	M	L	L	M	L	nd	M
U Myo Win	3(R,P,R)	N	MA	VL	VL	L	M	L	nd	L
U Thet	2a(R,P)	VL	MA	VL	L	M	M	L	nd	L
U Thein	2a(R,P)	L	SA	L	L	L	M	L	nd	L
	2a=6,3=5,2b=1	M=2	Acidic	M=6	L=12	M=2	L=0	L=12	nd	M=4

Appendix 5 Soil interpretation result on farmers' fields (Zeyarthiri Township)

Farmer	Cropping Pattern	FYM	pH	OC	T otal N	Avail P	Avai. K2O	Avai. S	Avai. Zn	Avai. B
U win	2a(R,P)	N	SA	M	L	L	M	L	nd	M
U min naing	3(R,P,R)	N	SA	M	L	L	M	L	nd	M
U thein win	2a(R,P)	N	MA	M	L	M	H	L	nd	M
U Ag Tun oo	2a(R,P)	L	SA	L	VL	M	M	L	nd	M
U ko gyi	2b(R,R)	N	SA	M	L	L	H	L	nd	M
U ko lay	3(R,P,R)	N	SA	M	L	L	H	L	nd	M
U thein M	2a(R,P)	N	SA	H	L	L	H	L	nd	M
D. P khaing	2a(R,P)	N	SA	M	L	L	H	L	nd	M
U kyaw lin	2a(R,P)	N	SA	H	L	L	H	l	nd	M
U M soe	2a(R,P)	N	EA	M	L	L	M	L	nd	M
	2a=7,3=2,2b=1	N=10	A=10	L=1	L=10(1)	L=8	M,H=10	L=10	ND=10	M=10

Appendix 6 Soil properties after harvesting in Pobbathiri (dry season, 2017)

Treatments	Total N%	Avai. P (mg kg^{-1})	Avai. K_2O (mg100g $^{-1}$)	Avai. SO_4 (meq100g $^{-1}$)	Avai. Zn (mg kg^{-1})	Avai. B (mg kg^{-1})
initial	0.16	5.87	13.96	0.20	nd	1.50
T_2	0.10	7.55	8.42	0.22	nd	1.20
T_3	0.13	2.71	3.64	0.20	nd	1.14
T_4	0.15	16.19	5.78	0.15	nd	2.64
T_5	0.10	15.59	0.76	0.05	nd	1.14
T_6	0.10	14.09	2.84	0.37	nd	0.82
T_7	0.16	16.55	0.88	0.05	nd	2.70
T_8	0.16	9.05	11.36	0.05	nd	2.76
$LSD_{0.05}$	0.02	0.94	0.73	0.02		0.14
Pr > F	**	**	**	**		**
C.V%	10.03	4.99	9.29	7.95		4.
	L	mostly Low	L	L	VL	M

Appendix 7 Soil properties after harvesting in Zeyarthiri soil (dry season, 2017)

Treatments	Total N%	Avai. P (mg kg^{-1})	Avai. K_2O (mg100g $^{-1}$)	Avai. SO_4 (meq100g $^{-1}$)	Avai. Zn (mg kg^{-1})	Avai. B (mg kg^{-1})
initial	0.12	13.33	9.06	0.2	2.63	1.2
T_1	0.12	10.06	1.66	0.24	2.08	1.05
T_2	0.05	13.9	2.9	0.22	2.4	0.88
T_3	0.05	2.78	2.5	0.2	3	0.81
T_4	0.12	23.26	0.04	0.1	2.5	0.31
T_5	0.05	22.61	0.1	0.1	4.2	0.81
T_6	0.05	20.98	0.14	0.36	1.78	2.5
T_7	0.12	23.65	0.25	0.1	5.09	2.37
T_8	0.12	15.53	6.08	0.1	4.93	2.44
$LSD_{0.05}$	0.02	1.39	2.09	0.03	0.26	0.19
Pr > F	**	**	*	**	**	**
C.V%	15.64	4.76	82.27	9.16	3.42	9.16
	L	mostly M	L	L	L/M	M

Appendix 8 Soil properties after harvesting in Pobbathiri experiment (wet season, 2017)

Treatments	Total N%	Avai. P (mg kg^{-1})	Avai. K_2O (mg100g $^{-1}$)	Avai. SO_4 (meq100g $^{-1}$)	Avai. Zn (mg kg^{-1})	Avai. B (mg kg^{-1})
initial	0.17	2.47	9.44	0.35	nd	0.85
T_1	0.13	3.05	0.20	0.05	nd	0.69
T_2	0.12	6.08	4.97	0.23	nd	0.59
T_3	0.08	2.60	5.30	0.20	nd	0.54
T_4	0.12	11.46	2.72	0.15	nd	2.04
T_5	0.12	12.80	3.34	0.15	nd	0.53
T_6	0.12	11.67	0.21	0.52	nd	2.20
T_7	0.17	13.77	2.50	0.20	nd	2.00
T_8	0.17	7.36	7.49	0.17	nd	2.14
$LSD_{0.05}$	0.02	6.32	0.58	0.04		0.23
Pr > F	**	**	**	**		**
C.V%	9.23	38.14	9.77	12.10		9.77
	L	L	L	L	VL	M

Appendix 9 Soil properties after harvesting in Zeyarthiri experiment (wet season, 2017)

Treatments	Total N%	Avai. P (mg kg^{-1})	Avai. K_2O (mg100g $^{-1}$)	Avai. SO_4 (meq100g $^{-1}$)	Avai. Zn (mg kg^{-1})	Avai B (mg kg^{-1})
initial	0.21	5.60	25.66	0.55	nd	0.24
T_1	0.15	2.35	12.93	0.10	nd	0.05
T_2	0.15	6.17	19.50	0.23	nd	nd
T_3	0.11	4.90	6.40	0.05	nd	0.15
T_4	0.12	13.35	16.64	0.30	nd	1.35
T_5	0.14	4.88	9.55	0.26	nd	0.15
T_6	0.14	13.25	13.45	0.31	nd	1.55
T_7	0.18	15.92	9.80	0.03	nd	1.41
T_8	0.20	7.79	22.68	0.26	nd	1.48
$LSD_{0.05}$	0.03	1.09	0.69	0.06		0.38
Pr > F	**	**	**	**		**
C.V%	11.78	6.38	2.84	17.94		28.16
	L	L	M	L	VL	L

Appendix10 Soil properties after harvesting in the pot experiment (wet season, 2018)

Treatments	Total N%	Avai. P (mg kg^{-1})	Avai. K_2O (mg100g $^{-1}$)	Avai. SO_4 (meq100g $^{-1}$)	Avai. Zn (mg kg^{-1})	Avai. B (mg kg^{-1})
initial	0.18	13.24	20.44	0.64	1.73	1.80
T_1	0.18	5.39	26.74	0.44	1.71	1.00
T_2	0.14	4.53	25.31	0.28	1.88	2.00
T_3	0.33	26.03	30.99	0.08	2.78	2.00
T_4	0.18	10.69	25.93	0.20	1.71	2.00
T_5	0.22	10.29	29.63	0.36	2.73	2.00
T_6	0.25	17.70	29.01	0.60	2.24	3.00
T_7	0.18	10.32	31.58	0.28	1.71	2.00
T_8	0.18	3.31	24.22	0.24	1.92	2.00
$LSD_{0.05}$	0.11	3.38	4.84	0.12	1.17	1.08
Pr > F	ns	**	*	**	ns	ns
C.V%	30.19	17.51	9.9	26.33	31.96	30.97
	L	L	M	L	L	M

Appendix 11 Mean Nutrient Accumulation in plant part with treatments (wet season, 2018)

Treat.	N%		P_2O_5 %		K_2O%		S%		Zn mg kg^{-1}		B mg kg^{-1}	
	grain	straw	grain	straw	grain	straw	grain	straw	grain	straw	grain	straw
T1	0.823	0.617	0.33	0.26	0.396	0.238	0.0287	0.0394	23.94	15	35	24
T2	0.823	0.48	0.35	0.14	0.343	0.396	0.0192	0.0293	20.3	9.3	18	23
T3	0.823	0.412	0.36	0.23	0.343	0.383	0.0148	0.0289	21.96	11.18	13	46
T4	0.823	0.274	0.35	0.11	0.369	0.264	0.0034	0.0173	23.04	14.1	30	36
T5	0.755	0.549	0.38	0.45	0.343	0.475	0.0092	0.0158	22.28	19.66	18	19
T6	0.823	0.412	0.33	0.44	0.343	0.202	0.0018	0.0109	21	21.2	11	14
T7	0.755	0.412	0.34	0.235	0.343	0.202	0.0378	0.0147	23.16	15.66	10	20
T8	0.686	0.412	0.38	0.23	0.369	0.374	0.0631	0.0081	22.06	14.24	25	36
C.V	1.45	6.58	7.76	8.03	12.09	8.62	1.41	10.35	0.58	3.18	4.62	11.65

Appendix 12   Nutrient concentration in grain and straw (wet season, 2018)

		percent								mg kg^{-1}			
Treat.	**Rep**	**N grain**	**N straw**	**P grain**	**P straw**	**K grain**	**K straw**	**S grain**	**S straw**	**Zn grain**	**Zn straw**	**B grain**	**B straw**
T1	R1	0.82	0.62	0.33	0.26	0.4	0.24	0.029	0.039	23.9	15	35	25
T1	R2	0.81	0.62	0.33	0.28	0.37	0.22	0.028	0.039	23.8	16.5	33	25
T1	R3	0.83	0.63	0.33	0.24	0.43	0.26	0.03	0.039	24	14.5	36.5	22
T2	R1	0.83	0.5	0.34	0.14	0.41	0.43	0.193	0.027	20.3	10	17	20
T2	R2	0.82	0.48	0.35	0.14	0.34	0.4	0.192	0.029	20.3	9.3	18	24
T2	R3	0.81	0.46	0.36	0.14	0.27	0.37	0.191	0.029	20.3	8.6	19	25
T3	R1	0.82	0.41	0.36	0.23	0.34	0.39	0.287	0.029	22	11.18	13	46
T3	R2	0.81	0.4	0.37	0.25	0.27	0.33	0.288	0.029	22	11	14	48
T3	R3	0.83	0.42	0.35	0.21	0.4	0.45	0.287	0.029	21.9	11.36	12.9	44
T4	R1	0.82	0.3	0.37	0.11	0.39	0.26	0.003	0.019	23.04	14.5	28.5	35
T4	R2	0.82	0.24	0.33	0.11	0.35	0.26	0.003	0.015	23.05	13.8	31.4	35
T4	R3	0.82	0.27	0.35	0.11	0.37	0.26	0.003	0.017	23.04	14.1	30	38
T5	R1	0.74	0.59	0.36	0.47	0.33	0.5	0.008	0.005	22.1	49.5	17.5	25
T5	R2	0.76	0.55	0.38	0.45	0.34	0.47	0.009	0.005	22.3	49.6	18	17
T5	R3	0.75	0.51	0.4	0.43	0.31	0.44	0.01	0.005	22.5	49.72	18.6	25
T6	R1	0.83	0.47	0.36	0.43	0.31	0.2	0.004	0.013	21	21	10.5	16
T6	R2	0.82	0.41	0.33	0.44	0.34	0.2	0.002	0.011	21	21.2	11	14
T6	R3	0.81	0.35	0.3	0.45	0.37	0.21	0.001	0.009	21.05	22.5	11.7	12
T7	R1	0.77	0.38	0.28	0.29	0.37	0.19	0.04	0.011	23.1	16	10	16
T7	R2	0.75	0.41	0.34	0.24	0.34	0.2	0.038	0.015	23.2	15.66	10	18
T7	R3	0.73	0.43	0.4	0.19	0.31	0.2	0.036	0.019	23.6	15.22	10	26
T8	R1	0.69	0.41	0.38	0.23	0.37	0.37	0.063	0.008	22.1	14.24	25	33
T8	R2	0.68	0.4	0.38	0.22	0.4	0.36	0.063	0.006	22	14.5	24	35
T8	R3	0.7	0.42	0.38	0.24	0.33	0.37	0.063	0.01	22.2	14.05	25.8	40

Appendix13 Yield and Yield components of Pot experiment (dry season, 2017)

Treat.	Soil	Ferililzer	Tiller hill^{-1}	Spik panical $^{-1}$	Filled Grain%	1000 Grainwt (g)	Yield t ha^{-1}	TDM t ha^{-1}
T_1	Pobbathiri soil	NPK	16.5	114.14	84.42bcd	27.31	7.66bc	21.82
T_2		+S	18	98.13	87.81abc	27.81	7.60bc	21.41
T_3		+Zn	17.17	102.32	89.26ab	27.55	7.33c	20.72
T_4		+B	16.5	110.97	88.39ab	27.83	7.84abc	21.65
T_5		+S +Zn	17.17	109.2	88.16abc	28.11	7.99abc	21.01
T_6		+S+B	17	109.02	91.02a	27.89	7.94bc	21.56
T_7		+Zn +B	18.83	106.04	91.27a	27.46	8.32ab	22.99
T_8		+S+ Zn B	17.33	113.03	90.06ab	28.15	8.28abc	20.49
T_9	Zeyarthiri soil	NPK	14.33	118.29	80.77d	27.22	7.65bc	24.05
T_{10}		+S	16.5	122.2	87.14abc	27.41	8.18ab	24.47
T_{11}		+Zn	16.5	105.7	87.19abc	28.28	7.84abc	22.59
T_{12}		+B	14.33	133.99	82.29cd	27.28	8.08abc	23.86
T_{13}		+S+Zn	15.83	134.57	88.92ab	27.41	8.66a	24.2
T_{14}		+S+B	16.83	116.29	89.24ab	28.39	8.37ab	23.04
T_{15}		+Zn+B	15.83	128.36	86.32abcd	27.89	8.67a	23.91
T_{16}		+S+Zn+B	16.67	124.47	90.00ab	27.67	8.76a	24.59
CV			9.47	10.81	4.15	2.49	7.06	8.9
P> 0.05 (T)			0.25	0.2058	0.0184	0.5262	0.02	0.84
P> 0.05 (S)			0.004	0.0002	0.0353	0.7313	0.02	0.0002
P> 0.05 (S &T)			0.68	0.5401	0.7031	0.4884	0.6	0.74
LSD			2.62	20.8	6.06	1.5	0.94	3.35

Appendix 14 Evaluation of soil nutrient level in Naypyitaw agricultural land

IJERD – International Journal of Environmental and Rural Development (2018) 9-2

Research article

Evaluation of Soil Nutrient Level in Naypyitaw Agricultural Land

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Received 22 December 2017 Accepted 25 October 2018 (*Corresponding Author)

Abstract Being one of the portions of land degradation, fertility depletion is a major barrier in crop productivity in Agricultural Sector. While we made attempt to increase crop productivity for food security, this study focused on investigating the fertility status of the soil and the major factors that influenced the nutrient level. The studies were carried out in Naypyitaw Union Territory during 2016 - 2017. The first study emphasized on major nutrient level in Naypyitaw region. A total of 240 soil samples were collected from 8 townships of 2 districts and analyzed. Soil analyses were performed for soil acidity, organic carbon, total Nitrogen, available P and K. Using descriptive statistic, the nutrient levels were evaluated in study area. The objective of second study was to evaluate the major and minor nutrient status in prominent specific rice fields in two townships. (Pobbathiri and Zeyar Thiri). Soil samples were collected from 22 farmer's fields and analyzed to identify soil macro and specific micro nutrients content. The Chi-square test was used to analyze for different location and different cropping patterns. First study showed that about 50% of Naypyitaw agricultural lands is low in Organic Carbon, 82% and 90% of land were also deficient in total N and available P, respectively. The second study showed that the deficiencies of total N, available P, S and Zn were detected in all rice fields. These nutrient deficiencies are not totally dependent on grown crops. It may be due to insufficient application of nutrients amount and type. It was also found that no farmers apply sufficient amount of organic and inorganic fertilizers. The results of the present study suggested that the effective education system was essential for farmers to adopt the advanced fertility technology regarding balanced fertilization of macro and micro nutrient..

Keywords balanced fertilization, degradation, macro, micro, fertility depletion

Appendix 15 Evaluation of balanced macro and micro nutrient application in rice cultivation

Evaluation of Balanced Macro and Micro Nutrient application in rice cultivation

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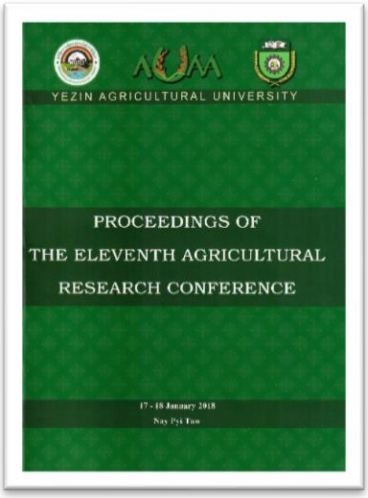
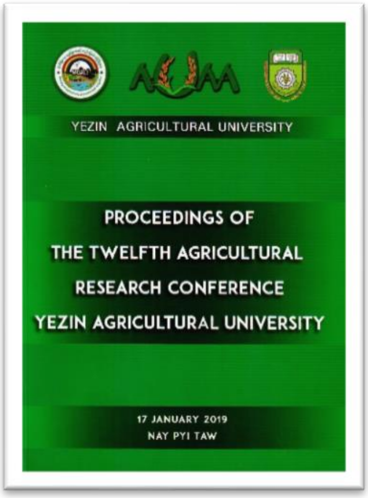
Abstract

While Myanmar is trying to attempt the development of sustainability in Agricultural sector, increasing crop productivity and maintaining the natural resources is equally important. To meet this aim, balanced fertilization not only in macro but also in micro nutrients is essential especially in rice production. Therefore this experiment was conducted at Department of Soil and Water Science in YAU to evaluate the macro and micro nutrient application on rice yield. It was laid out as factorial arrangement in RCB design with 3 replications. Factor A was 2 soils from different location (YAU field and Pobbathiri farmer 's field). Factor B was 8 treatments with different nutrients as (1) NPK (2)+S (3)+Zn (4) +B (5) +S, Zn (6)+S, B (7) +Zn, B (8)+S ,Zn ,B . Basal NPK rate were 85kg N,30 kg P and 37 kg K per hectare. The rate of additional nutrients were 30 kg S, 5 kg Zn and 3 kg B per ha. All data were analyzed by using STATASTIX version 8.0. The 1000 seed weight and panicle length were not significantly different in both 2 factor. Filled grain %, yield and harvest index were found significantly differences by factor A in 0.05% level. No of tiller/hill, Spikelet/panicle and total dry matter were highly significantly different based on soil. Among the treatments, filled- grain percent and yield were found significantly differences with 0.05% level. The highest yield was found in T_8 (8.52 t ha^{-1}) follow by T_7, T_5 and so on. Therefore Zn may be great important but its alone (T_3) is not effective in increasing yield. The individual effect of micro nutrient in yield is not too much but their combination effect would give higher in yield in rice cultivation.

Keywords: macro nutrient, micro nutrient, sustainable, balanced fertilization, additional nutrient



Appendix 16 Evaluation of balanced major and minor nutrient application in rice cultivation



Evaluation of Balanced Major and Minor Nutrient Application in Rice Cultivation

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Abstract

It has been well known that crop required major nutrients N,P and K as essential for crop growth and economic yield, however minor nutrients such S ,Zn and B are also become crucial for crop productivity since high cropping intensity was developed in modern agriculture. Not only major nutrients but also minor nutrients are to be considered for crop productivities and extended to long term sustainability with balanced fertilization. Therefore this experiment was conducted in major rice growing area in Zayarthiri Township. Experiment was carried out in 2017 monsoon season and Yadanatoe was used add tested variety. Treatments were +S, +Z, +B, +S and Zn, +Sand B, + Zn and B , and +S+Zn+B with NPK. Design was laid out in RCB design with 8 treatments, 3 replications containing 24 plots in each plot size of (5x5)m. The result showed that filled grain percent and yield were significantly different among treatments. Other yield components were not found significantly differences. Based on this research, additional treatment of (S, Zn, B) can increase filled grain percent and the most significant result was found in Zn and B treatments. Yield may be also increased by addition of minor nutrients with (N,P,K). The S treatment (T2) gave 10.9 percent yield increased and 12.29 percent by Zn(T3) and 13.52 percent by adding B nutrient (T4). The treatment that including all nutrients gave the highest yield of 7.66 Ton per hectare in percent of 17.20 over control.

Keywords: balanced fertilization; nutrient; sustainability