**Ph.D. Thesis**

# Effects of compost produced from cyclical food resources on the growth and yield in rice plant

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# Chapter One

## Introduction

The application of chemical fertilizers is costly and their overuse gradually hazards to human health and the environment. Continuous application of inorganic fertilizers often reduces the amount of soil organic matter and acidifies the soil, leading to undesirable effects on the microbial and nutrient dynamics. In recent years, application of chemical fertilizers have largely replaced with organic fertilizers for high and quality agricultural productions. Organic residue recycling is becoming an increasingly important aspect of environmentally sound for sustainable agriculture. Now-a-days, agriculture production based on organic application is growing in interest. The application of organic matter is fundamentally important in that they supply various kinds of plant nutrients, improve soil physical and chemical properties and hence nutrient holding and buffering capacity, and consequently enhance microbial and enzymatic activities of soil (Clark *et al.*, 1998; Albiach *et al.*, 2000; Eneji *et al.*, 2001; Zaman *et al.*, 2002).

There are several kinds of organic materials, including husk manure, cattle manure (Asai *et al.*, 2016), rice bran (Bian *et al.*, 2010), cow and chicken manure (Saitoh *et al.*, 2001), farmyard manure (Maeda *et al.*, 2005), poultry manure compost (Arisawa *et al.*, 2015), and other materials. The impact of organic matter as fertilizer has been seen over time in providing growth regulating substances and providing many kinds of plant essential elements, both macro-elements and micro-elements to produce good quality of agricultural production that are environmentally safe, agronomically advantageous and relatively cheap. Mohammad (1999) and Baziramakenga and Simard (2001) reported that organic materials contained many essential elements at low concentrations, which were slowly released upon decomposition. The use of composts to fertilize agricultural land has been beneficial, from the perspective of a recycling economy and because of their valuable characteristics and ingredients (Clark *et al.*, 1998).

Furthermore, several studies have been conducted on the effects of organic materials on the growth and yields of rice plants (Eneji *et al.*, 2001; Ojobor *et al.*, 2014). Application of manure enhanced the nutrient uptake and dry matter yield of the rice plants (Marchesini *et al.*, 1988; Eneji *et al.,* 2001).

The world must feed 9 billion people by 2050. The demand for food will be 60 % greater than it is today (FAO, 2013). On the other hand, approximately one-third of the edible part of food produced for human consumption gets lost or wasted globally, which is about 1.3 billion ton per year (FAO, 2011). To meet the heavy demand for food of the growing population and manage the waste problem, it is necessary to think about a range of innovative solutions to recycle the wastes and improve food production. Food waste and sewage sludge can be found in large amounts in every country (Thi *et al.*, 2015) and their disposal is a challenge in developed countries. METI reported that food waste in Japan amounted to 6.42 million tons per year (METI, 2016). FUSIONS reported that the EU generated 88 million tons of food waste annually (EU, 2016). Annual food waste in the USA was estimated at 31.75 million tons (70 billion pounds) (Feeding America, 2017). Per capita food waste in developed countries and developing countries are 107 and 56 kg per year, respectively (Thi *et al.*, 2014). Sewage sludge is one of the final products of the treatment of sewage at wastewater treatment factories.

In Japan, farmers prepare most of these manures from organic waste, such as crop residues and animal excreta. Some animal manure composts contain heavy metal components at high concentrations (Orihara *et al.*, 2002). The amount of compost applied to paddy fields was 545g $m^{-2}$ in 1965 but it was 125 g $m^{-2}$ in 1997 (Inomata, 2002). As for the decrease in compost application, degradation of soil fertility in paddy field was inevitable. After the Food Recycling Law of Japan (2000) was enacted, food waste compost (FWC) and sewage sludge compost (SSC) as new types of compost are producing by composting companies. Under the fertilizer regulation act, SSC and FWC have been classified as ordinary fertilizer and special fertilizer, respectively. SSC is thought to cause little environmental pollution, as it is controlled for the level of heavy metals and does not contain domestic animal excreta. FWC also causes minimal environmental pollution for the similar aforementioned reasons. Although the level of heavy metals in these composts are considered to be below the reference value, they must be applied at an appropriate rate and amount to avoid environmental pollution. These composts mainly produced from food wastes, wood chips, grass clippings and sewage sludge of food factories. These compost do not produce from manure or animal excreta (Nagaya, 2007).

Composts made from food wastes and sewage sludge can be an important organic fertilizer in crop production from the viewpoint of containing nitrogen (N), phosphorus (P), potassium (K) and other plant nutrients, recycling the wastes, conserving resources and the environment. In addition, compost continuously releases N as plant need. Asagi *et al*. (2007) reported that sewage sludge with a low concentration of heavy metal can be regarded as a useful organic fertilizer from the viewpoint of nutrient supply for soil fertilization and nutrient recycling in the environment. SSC and FWC produced from cyclical food resources were procured using the new business model, which established a food recycle loop among farmers, food shops, and waste processing companies (MOE, 2014). But there are only few cases of SSC and FWC use in rice production.

On the other hand, N is an essential metabolic element and one of the most important factor having great impact on growth and development of plants, it is considered as essential for synthesis of protein and other biochemical products of plant such as protoplasm which is the basis of life therefore, nitrogen directly concerned with physiological process occurring within plants. Although, nitrogen is the most important element which plays the vital role in rice nutrition as it is required throughout the growing period of the crop.

The nitrogen concentration of SSC and FWC was relatively high from the analysis results of many animal manure compost (Hioki *et al.*, 2001). So, appropriate dose of nitrogen should be applied for rice plant when SSC and FWC are going to use. Because, high amount of compost based on high nitrogen application might affect the growth of rice plant. The mineralization of compost is a complex process which is caused by many environmental factors such as soil physicochemical properties, temperature, soil moisture and biota (Oyanagi *et al.*, 2002). Therefore, rate of decomposition and the mineralization process of SSC and FWC might make it difficult to appropriately control the amount of nutrient especially nitrogen (N) supply to the rice plants during the different growth stages and it might affect the growth and yield of rice plant. Nagaya *et al.* (2013) reported in a pot experiments that using SSC-like compost application had inhibiting effect on initial growth of rice plant. Nishikawa *et al.* (2013) also reported in his field experiment that application of anaerobically-digested manure (ADM) has temporal inhibition effect on growth parameters of rice plants, from transplanting to the active tillering stage compared to chemical fertilizer.

Side dressing of FWC and SSC is a new method of basal dressing to rice plants. This method might promote the initial growth, save labor for fertilizer application, and increase fertilizer use efficiency.

In the light of the above viewpoints, it is important to investigate and elucidate the effects of compost mainly produced from food waste and sewage sludge (FWC and SSC) with different nitrogen levels, different seasonal repetition, and different method of application on growth and yield of rice. Therefore, it was planned to conduct the three below experiments.

1. Effects of food- and sludge-derived compost with different nitrogen levels on growth and yield of rice (*Oryza sativa* L.)
2. Effects of different compost with different nitrogen levels on the early growth stage of rice (*Oryza sativa* L.)
3. Effects of different application methods of different composts (SSC and FWC) on the growth and yield of rice (*Oryza sativa* L.)

* * *

# Chapter Two

## Effects of food- and sludge-derived compost with different nitrogen levels on growth and yield of rice (*Oryza sativa* L.)

Crop production uses the cyclical functions of nature. Organic materials are applied to soil as fertilizers and conditioners to enhance crop production. There are several kinds of organic materials, including husk manure, cattle manure (Asai *et al*., 2016), rice bran (Bian *et al*., 2010), cow and chicken manure (Saitoh *et al.*, 2001), farmyard manure (Maeda *et al.*, 2005), poultry manure compost (Arisawa *et al.*, 2015), and other materials. The application of organic matter is fundamentally important in that they supply various kinds of plant nutrients including both macro- and microelements, improve soil physical and chemical properties and hence nutrient holding and buffering capacity, and consequently enhance microbial and enzymatic activities of soil (Clark *et al*., 1998; Albiach *et al*., 2000; Eneji *et al*., 2001; Zaman *et al*., 2002). Organic matter can be potential important sources of nitrogen (N), which is often the most limiting element for plant growth and quality. In addition, organic matter continuously releases N as plant need it.

Food waste and sewage sludge can be found in large amounts in every country (Thi, *et al*., 2015). Per capita food waste in developed countries and developing countries are 107 and 56 kg per year, respectively (Thi, *et al.*, 2014). In 2017, METI reported that food waste in Japan amounted to 6.42 million tons per year (METI, 2016). FUSIONS reported that the EU generated 88 million tons of food waste annually (EU, 2016). Annual food waste in the USA was estimated at 31.75 million tons (70 billion pounds) (Feeding America, 2017).

The farmers in Japan were used compost and manure which were produced from crop residues and animal excreta. After the Food Waste Recycling Law of Japan (2000) was enacted, food waste compost (FWC) and sewage sludge compost (SSC) emerged as new types of compost. These composts are mainly produced from cyclical food resources, such as food waste, food processing residues and sewage sludge from food factories, wood chips, and grass clippings. In terms of waste treatment process and procurement method of raw materials, these composts are different from the ones used so far. And both composts did not contain animal excreta (Nagaya, 2007). Some animal manure composts contain heavy metal components at high concentrations (Orihara *et al.*, 2002).

SSC and FWC produced from cyclical food resources were procured using the new business model, which established a food recycle loop among farmers, food shops, and waste processing companies (MOE, 2014). As well, composts made from food wastes and sewage sludge can be an important organic fertilizer in crop production from the viewpoint of containing N, phosphorus (P), potassium (K) and other plant nutrients, conserving resources and the environment and they are relatively cheap. SSC and FWC are thought to cause little environmental pollution, as they are controlled for the level of heavy metals and do not contain domestic animal excreta. Asagi *et al.*, (2007) reported that sewage sludge with a low concentration of heavy metal can be regarded as a useful organic fertilizer from the viewpoint of nutrient supply for soil fertilization and nutrient recycling in the environment. As well, several studies have been conducted on effect of organic materials on growth and yield of rice plant (Eneji *et al.*, 2001; Ojobor *et al.*, 2014). But there are only few cases of SSC and FWC use in rice production. On the other hand, rate of decomposition and the mineralization process of different organic materials make it difficult to appropriately control the amount of nutrient supply to the rice plants during their growth.

The objectives of this study were (i) to investigate the effects of the application of SSC and FWC on the growth and yield of rice plants, (ii) comparison of two kinds of compost (SSC and FWC) with each other and with chemical fertilizer, and (iii) identify the safety and relatively high yield condition by application of different N level of SSC and FWC. Therefore, the effects of SSC and FWC application with different nitrogen levels on the growth and yield of rice plants was investigated and elucidate in this study.

## Materials and Methods

The present investigation entitled "Effects of food- and sludge-derived compost with different nitrogen levels on growth and yield of rice (*Oryza sativa* L.)" was conducted during 2015-2016 for two years. The details about the climatic under which the present investigation was carried out, experimental material used, techniques employed and criteria for evaluation of treatments during the course of investigation have been described as below.

### Site description

The two years pot experiments were conducted at the Experimental Field of Mie University, Mie, Japan in 2015 and 2016, which is geographically located in Tsu city in the Kansai region on the island of Honshu in the central part of Japan, at latitude 34° 43′ 6.96″ North and longitude 136° 30′ 20.51″ East with an elevation of about 2 meters above mean sea level. Tsu city has a humid subtropical climate with hot summers and cool winters. Precipitation is significant throughout the year, but is heaviest from May to September.

The every 10 days mean weather data such as 10 days average temperature (°C) and total rainfall (mm) during the crop seasons from April 1$^{st}$ to the end of September 2015 and 2016 were recorded from local meteorological observatory located in Tsu city.

**Composting process**

We used two types of compost; Food Waste Compost (FWC) and Sewage Sludge Compost (SSC) made by MCS Co. Ltd., Tsu city, Mie prefecture, Japan. FWC was prepared by mixing the raw-materials of food waste, wood chips and grass clippings and composting them in volumes of 100-300 $m^3$, while being rotated in a wheel loader. The time to reach maturity for FWC was "middle mature" which is 1.5 to 2 months. SSC was prepared by mixing raw-material of food waste, wood chips, grass clippings and sewage sludge from food companies and composting them in volumes of 1000 $m^3$, while being rotated in a scoop-type compost agitator. The time to reach maturity for SSC was the same as that for FWC. Table 1.1. Summarizes the chemical and physical characteristics of these composts.

**Table 1.1. Chemical and physical properties of composts.**

| | SSC | FWC |
|---|---|---|
| C (total carbon) (g $kg^{-1}$) | 346.0 | 366.0 |
| N (total nitrogen) (g $kg^{-1}$) | 61.0 | 46.0 |
| C/N Ratio | 5.7 | 7.8 |
| pH ($H_2O$, 1:10) | 6.8 | 7.2 |
| Electrical Conductivity (mS/$cm^{-1}$) | 8.4 | 5.9 |
| $P_2O_5$ (g $kg^{-1}$) | 31.0 | 17.0 |
| $K_2O$ (g $kg^{-1}$) | 18.9 | 15.9 |
| Moisture (%) | 31.6 | 30.6 |

Concentration is expressed as dry basis.
Sampling day of compost was 1st April, 2015.

**Treatments and experimental design**

The pot experiments were arranged in randomized block design (RBD) with 3 replications. Experiments were conducted under open field conditions from April 29 to September 17 in 2015 and from April 29 to September 9 in 2016. The containers (24 L) with dimensions of 46.4 cm (length) × 23.4 cm (width) × 22 cm (height) were used as pot in these experiments. Hereafter pot will use instead of container. In a block, 10 pots were arranged closely with the short side facing the north-south direction. The three blocks were placed parallel to each other and spaced 70 cm from the adjacent block.

Treatments included 2 types of compost (SSC and FWC), each with 4 levels of nitrogen (5.5, 11.0, 16.5, and 22.0 g N per pot) N levels specified the amount of each compost applied, one chemical fertilizer (CF) treatment at standard level (6.1 g N per pot) as control and no fertilizer (NF) treatment to determine the degree of soil fertility. The 10 treatments' names were abbreviated as $S_1$, $S_2$, $S_3$ and $S_4$ for four N levels of SSC; $F_1$, $F_2$, $F_3$, and $F_4$ for four N levels of FWC, CF for chemical fertilizer and NF for no fertilizer. The N content per pot of $S_1$ and $F_1$ was 5.5 g; $S_2$ and $F_2$ was 11 g; $S_3$ and $F_3$ was 16.5 g; $S_4$ and $F_4$ was 22 g; CF was 6.1 g and NF was 0 g (Table 1.2). The experiment was repeated for 2 years (2015 and 2016).

**Table 1.2 Treatments and total nitrogen (N), $P_2O_5$ and $K_2O$ levels.**

| Treatments | Source of nutrients | Total Nitrogen per pot (g) | $P_2O_5$ per pot (g) | $K_2O$ per pot (g) |
|---|---|---|---|---|
| **$S_1$** | Sewage | 5.5 | 2.8 | 1.7 |
| **$S_2$** | Sludge | 11.0 | 5.6 | 3.4 |
| **$S_3$** | Compost | 16.5 | 8.4 | 5.1 |
| **$S_4$** | (SSC) | 22.0 | 11.2 | 6.8 |
| **$F_1$** | Food | 5.5 | 2.0 | 1.9 |
| **$F_2$** | Waste | 11.0 | 4.0 | 3.8 |
| **$F_3$** | Compost | 16.5 | 6.1 | 5.7 |
| **$F_4$** | (FWC) | 22.0 | 8.1 | 7.6 |
| **CF** | Chemical Fertilizer | 6.1 * | 9.1 | 7.1 |
| **NF** | No Fertilizer | 0 | 0 | 0 |

SSC and FWC were applied uniformly as basal dressing. *CF was applied 5.3 g N as basal ($N:P_2O_5:K_2O$=12:18:14) for growth survey, and 0.8 g N as top dressing ($N:P_2O_5:K_2O$=14:0:14) for yield survey in 2017.

## Soil and Pots preparation

The paddy field was ploughed with soil-turning plough two months before transplanting, the 20 cm surface soil of the ploughed paddy field was collected, sieved and mixed together. Afterward, all the soils were kept in containers under similar condition for uniformity moisture level of all soil for two months. The soil was sandy loam soil with an initial pH of 6.2 and an electrical conductivity (EC) of 0.6 mS/cm. 3 days before transplanting each 24 L pot (46.4 cm × 23.4 cm × 22 cm) of the experiments was filled with 22 kg (uniformed fresh weight) of the prepared paddy soil.

## Application of compost and chemical fertilizer

Two types of composts (SSC and FWC) with different levels of N were applied to each treatment pot one day before transplanting. The amount of compost was depend to the percentage of total nitrogen content of each compost and its level. Therefore, the same weight of compost applied to the pot, the same weight of soil was removed from the pot. CF was applied as basal dressing and top dressing, phosphorus and potassium at the rate of 7.92 and 6.16 g per pot, respectively plus 5.28 g per pot nitrogen were applied at basal dressing (one day before transplanting) whose component was 12:18:14% of $N:P_2O_5:K_2O$. At top dressing 0.77 g per pot N was applied (July 1$^{st}$) whose component was 14:0:14 of $N:P_2O_5:K_2O$. Each pot was filled with either fertilizer (SSC/FWC/CF) and uniformly mixed with soil one day before transplanting.

## Variety used

Koshihikari a variety of japonica rice (*Oryza sativa* L.) was used in this experiment. Koshihikari was first developed in 1956, by combining 2 different strains of Nourin

No.1 and Nourin No.22 at the Fukui Prefectural Agricultural Research Facility. It has become very popular now in Japan, in part due to its good appearance.

**Sowing and seed rate**

The rice (*Oryza sativa* L.) cultivar "Koshihikari" seeds were soaked in water for 3 days at 30 °C temperature. Pregerminated seeds at the rate of 150 g was sown in the nursery boxes (58cm × 28cm × 3cm) which were filled with sterilized soil on 1$^{st}$ April 2015 and 2016. The nursery boxes were located in the greenhouse under controlled temperature condition until four-leaf stage.

**Transplanting**

Seedlings were separated based on their leaf age and the seedlings at four-leaf stage were selected and transplanted into the pots on 29$^{th}$ April 2015 and 2016.

**Spacing**

Plant density was 2 seedlings per hill and 4 hills per pot, the space between each hill was 12 cm. At the initial growth stage all the pots were located beside each other but after maximum tillering stage the pot were separated and the distance between each pot was 70 cm.

**Irrigation management**

The irrigation supplied from groundwater, it was started from one day before transplanting, the prepared pots were irrigated up to 1 cm above soil surface one day before transplanting of the seedlings and the pots were continuously submerged at a depth of approximately 3 cm from transplanting to harvesting of the plants.

**Inter-culture**

Weeding was done manually with the help of pincer every week from two weeks after transplanting. No chemical was used for weed control. Insects, and diseases were controlled as required to avoid yield loss.

**Harvesting**

The central two hills were selected for harvesting and the side plants in each pot were used as border plants. The whole plants of two central hills in each pot were harvested separately at their maturity stages and banded with tags. The harvesting was done manually with the help of sickle. The harvested material of each hill was air dried in greenhouse for 20-30 days.

**Observations recorded**

In order to secure the effects of different treatments, the plant growth parameters (leaf emergence pattern, plant length, tiller numbers, soil pH, soil-plant analysis development value, heading and maturity date) and yield components observations (top air-dry weight, weight of winnowed rough rice, straw weight, number of productive panicle, average number of spikelet per panicle, percentage of ripened grains, 1000-winnowed rough rice weight, culm length, panicle length, internodes length, maximum tiller number per hill, number of grain per panicle, percentage of productive culms and etc.) were recorded during the course of current pot experimentation.

**Plant growth parameters**

The two inner plants were measured for plant growth parameters (leaf emergence pattern, plant length and tiller numbers), avoiding the outer two plants for edge effects. Leaf emergence pattern, plant length and tiller numbers were recorded each week starting at 14 days (in 2015) and 13 days (in 2016) after transplanting. The growth data were collected from the central two hills in each pot. The side hills' plants in each pot were used as border plants. The data of leaf emergence pattern and plant length in cm where recorded until the appearance of flag leaf. The tiller numbers including maximum tiller number and productive tillers were counted until heading stage of each treatment.

**Soil pH**

Soil pH was determined for 6 weeks by digital pH meter (PRN-41, FUJIWARA) started from one week after transplanting (WAT) in 2015 and two WAT in 2016. The soil pH from 5-10 cm depth of two points in each pot was determined. The pH of two points was averaged to get per pot pH value.

**Soil-plant analysis development (SPAD) value**

The Soil-plant analysis development (SPAD) values were measured using SPAD-502 chlorophyll meter (KONICA MINOLTA Co.). The chlorophyll meter calculates a numerical SPAD value which is proportional to the amount of chlorophyll present in the leaf. 6 SPAD values per leaf, including two value around the midpoint of leaf blade and 4 values at 3 cm apart from the midpoint to the top were averaged as the mean SPAD value of the leaf (Peng *et al*., 1993). The SPAD value was measured from the uppermost three leaves of the main stem (Flag leaf, second leaf and third leaf) of each plant of one hill for three times, the first time at heading stage (50 percent heading), second time 10 days after heading stage and the third time 20 days after heading. The data of all plants per hill and two inner hills of one pot was averaged to know the SPAD values of flag leaf, second leaf and third leaf per hill.

**Heading and maturity date**

After the emergence of flag leaf, number of heading per hill was counted every day at 11:00 o'clock. The date when 50 percent of total tiller numbers emerged, was recorded as heading stage. Observation of heading continued until full heading stage, when 80 percent of the total panicles emerged. 30 days after heading stage, the data of maturity was recorded every day until harvesting.

**Yield components measurements**

The whole plants of two interior hills in each pot were harvested at ground level separately at their maturity stages and banded with tags. The harvested material of each hill was air dried in the greenhouse for 20-30 days, then the data of yield components were recorded as below:

**Top air-dry weight**

After harvesting and air dried, the whole top biomass dry weight of each hill was measured in gram and the dry weight of two hills of the same pot was averaged to get top air-dry weight per hill.

**Weight of winnowed rough rice**

For winnowed rough rice, the threshed grains were separated into fully-ripened grains and other grains (no mature grains) using a 1.06 g $mL^{-1}$ saline solution. The weight of the fully ripened grains of each hill was determined in gram after drying for 3 days at 80 °C in a ventilated oven, fully ripened grains weight of two hills of the same pot was averaged to get fully ripened grains weight per hill. Here after fully ripened grains weight will define as the weight of winnowed rough rice.

**Number of productive panicle**

The nonproductive panicles were separated from productive panicle after harvesting and the number of productive panicles per each hill was counted and the average of two hills of the same pot is the number of productive panicle per hill.

**Average no. of spikelet per panicle**

Concerning the average number of spikelet (flower) per panicle, it was computed with the help of following formula:

$$\text{Average no. of spikelet per panicle} = \frac{\text{No. of mature grain} + \text{No. no mature grain}}{\text{No. of productive panicle}}$$

**Percentage of ripened grains**

Percentage of ripened grains was calculated with the help of following formula:

$$\text{Percentage of ripened grains} = \frac{\text{No. of mature grain}}{\text{No. of mature grain} + \text{No. of no mature grain}} x100$$

**1000-winnowed rough rice weight**

Three samples of 500 grains (winnowed rough rice) of each hill were counted separately with Multi Auto Counter (Model: DC-1M5, Fujiwara scientific company, Tokyo, Japan) and their weight in gram was recorded, then weight of initial three samples of 500 grains was used to calculate and get the 1000-winnnowed rough rice weight.

**Straw weight**

The grain yield was separated from the harvested materials of each hill and the remaining was weighted in gram as straw weight, the straw weight of two hills of the same pot was averaged to get the straw weight per hill.

**Culm length**

The tallest tiller of each hill was selected after harvesting, then the panicle was separated from the upper end nod and the culm length was measured in cm. afterward, the culm length of two hills of the same pot was averaged to obtain the culm length per hill.

**Panicle length**

The separated panicles from tallest tiller were used to measure the panicle length. The panicle length of each hill was recorded in cm. The average of two hills in the same pot shows the panicle length per hill.

**Statistical analysis**

The data obtained from different observations on growth and yield components were subjected to statistical analysis. The mean data of each treatment was computed and used in tables and figures. One-way, two-way and three-way analysis of variance (ANOVA) were performed. Tukey multiple comparisons test at 5% level of probability was performed using BellCurve software for Excel (Social Survey Research Information Co. Ltd., Tokyo, Japan) to know the differences among the treatment.

## Results

### Crop weather relationship

The performance of the rice plant is highly influenced by prevailing weather conditions, therefore data of rainfall and temperature collected during the crop seasons. Fig. 1.1 shows the 10 days average temperature (°C) and the amount of rainfall (mm) during the experiments from April 1$^{st}$ to the end of September 2015 and 2016 in Tsu city, Mie Prefecture. In comparison to 30 years (1981-2010) average data of temperature and rainfall it was assumed that the weather conditions during the experimental period was normal in both years.

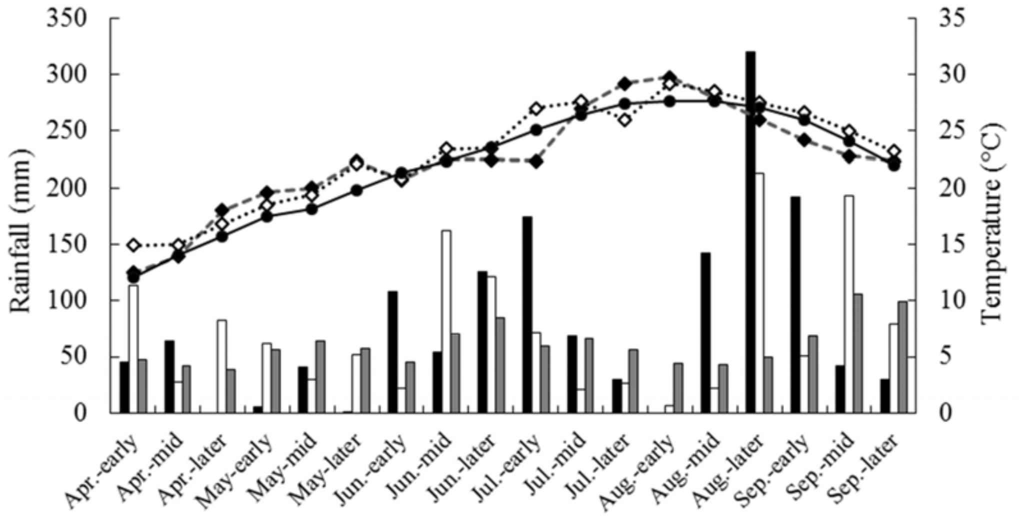



**Fig. 1.1. Measurements of temperature and rainfall during April–September in 2015 and 2016.**

**Effects on plant growth characters**

The results of this study show obviously effects of application of SSC and FWC with their levels on plant growth parameters of rice. Leaf emergence pattern, plant length, tiller number, soil pH and SPAD value were differed by different compost and their levels. The leaf emergence pattern, plant length and tiller numbers in SSC treatments were found higher than those of FWC treatments in all growth stages of 2015 and 2016.

**Leaf emergence pattern**

The means of leaf emergence pattern of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 are shown in Fig. 1.2 and Fig. 1.3, respectively and Table 1.3.

Leaf emergence pattern of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$) in 2015 were found lower than control treatment CF until 12 WAT, afterward, leaf emergence pattern of treatment $S_4$ increased over control treatment CF. However, Control treatment NF (no fertilizer) recorded the lower leaf emergence pattern than SSC treatments. At late growth stage (14 WAT) treatment $S_4$ recorded the highest leaf emergence pattern (15.8), treatments $S_3$ and CF were at par (15 and 15.1, respectively) and followed by treatments $S_2$ (14.7) and the lower was found in treatments $S_1$ (14.2) (fig. 1.2). In 2016 the leaf emergence pattern of SSC treatments were also found lower than treatment CF until 12 WAT. At the late growth stage treatment $S_4$ was recorded maximum and at par with treatment CF. In comparison to treatment NF, the leaf emergence patter of treatments S3 and S4 were lower than NF until 6 WAT, after that increased by increasing levels of SSC (Fig. 1.3).

Leaf emergence pattern of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) in 2015 were found significantly smaller than control treatment CF until 13 WAT, afterward leaf emergence pattern of treatment $F_4$ increased over control treatment CF. Treatment $F_1$ until 5 WAT, treatment $F_2$ until 7 WAT, treatment $F_3$ until 8 WAT and treatment $F_4$ until 10 WAT were even smaller than treatment NF (no fertilizer). At late growth stage (14 WAT) treatments $F_4$ recorded the higher leaf emergence pattern (15.6) treatments $F_3$, $F_2$ and CF were at par (15.3, 15.2 and 15.1, respectively) and the minimum was found in treatments $F_1$ (14.1) (Fig. 1.2). In 2016 leaf emergence pattern of FWC treatments were found smaller than treatment CF throughout the plant growth. At 12 WAT it was no significant difference among different FWC treatments and they were higher than control treatment NF, while at initial growth stage all FWC treatments were smaller than control treatment NF until 10 WAT (Fig. 1.3).

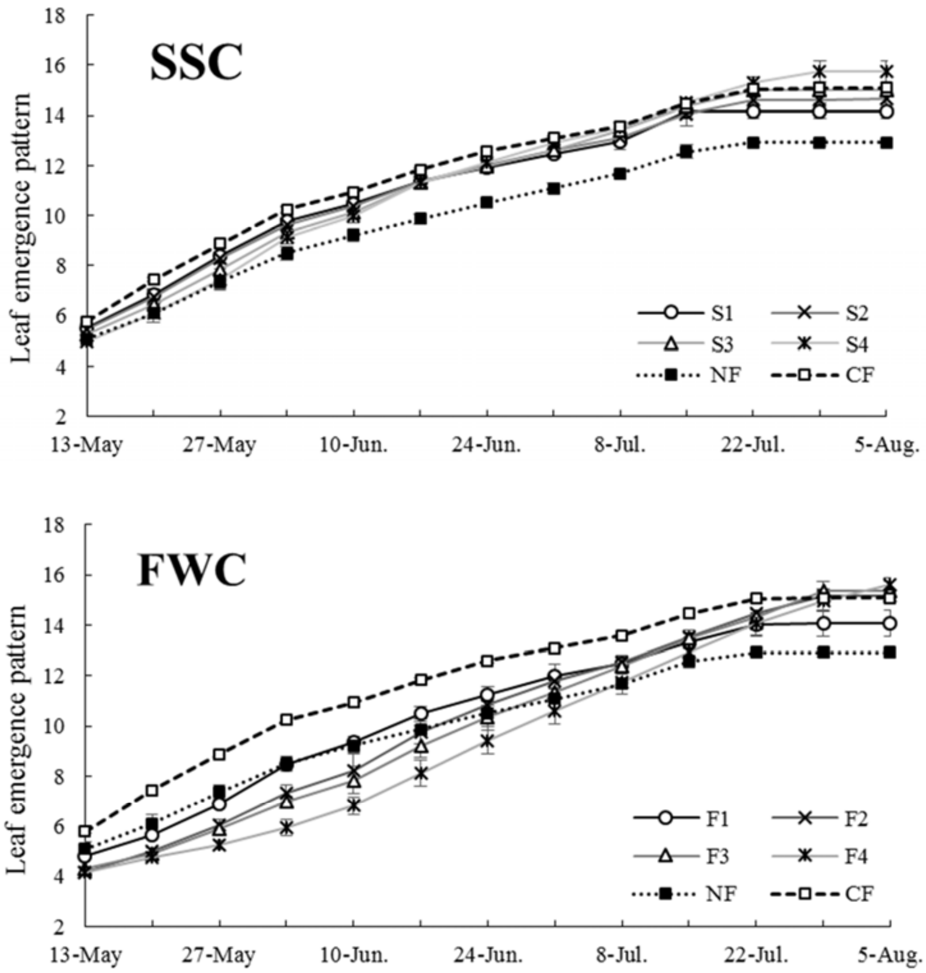
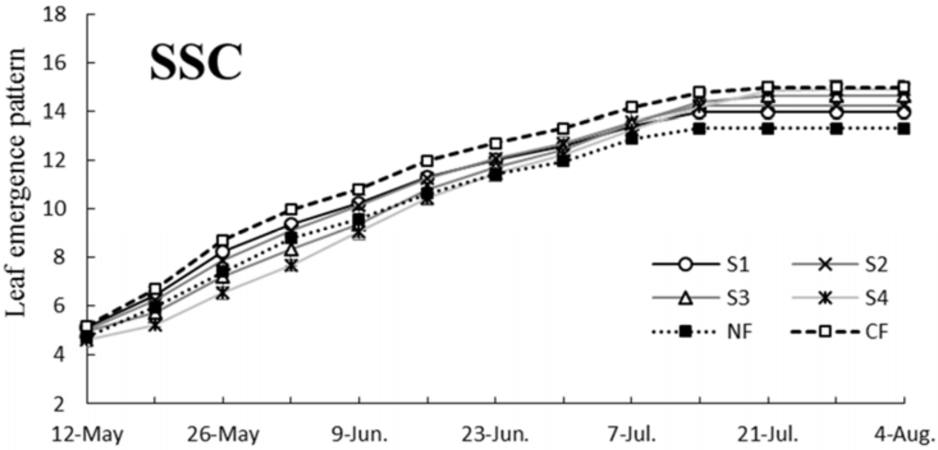



**Fig. 1.2. Effects of SSC and FWC treatments on the rate of leaf emergence in 2015.**
Data represent mean ± standard deviation (SD) (n = 3).



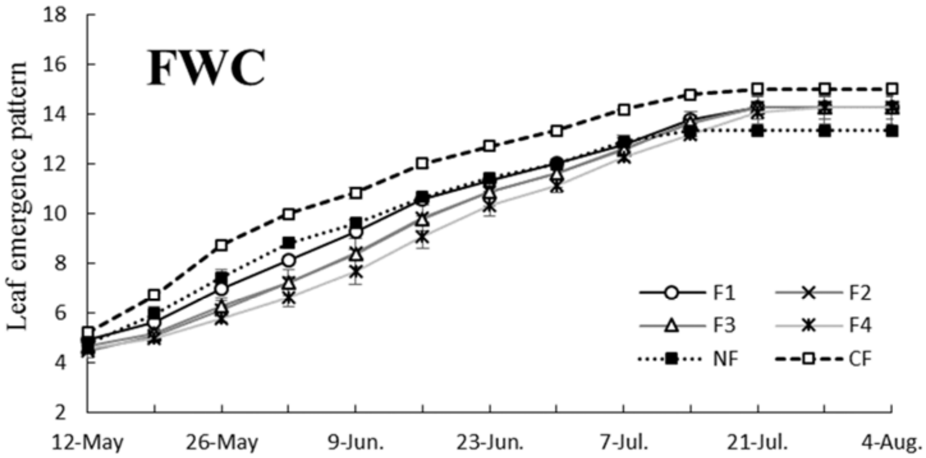




**Fig. 1.3. Effects of SSC and FWC treatments on the rate of leaf emergence in 2016.**
Data represent mean ± standard deviation (SD) (n = 3).

**Table 1.3. Means of Leaf emergence pattern.**

| Year | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul | 29-Jul | 5-Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | S1 | 5.5 | 6.9 | 8.4 | 9.8 | 10.5 | 11.4 | 11.9 | 12.5 | 13.0 | 14.2 | 14.2 | 14.2 | 14.2 |
| | S2 | 5.5 | 6.7 | 8.3 | 9.7 | 10.4 | 11.4 | 12.0 | 12.6 | 13.1 | 14.0 | 14.6 | 14.6 | 14.7 |
| | S3 | 5.2 | 6.5 | 7.9 | 9.3 | 10.1 | 11.3 | 12.0 | 12.6 | 13.4 | 14.4 | 15.0 | 15.0 | 15.0 |
| | S4 | 5.0 | 6.1 | 7.5 | 9.1 | 10.0 | 11.3 | 12.1 | 12.9 | 13.5 | 14.5 | 15.3 | 15.8 | 15.8 |
| | F1 | 4.8 | 5.7 | 6.9 | 8.5 | 9.4 | 10.5 | 11.3 | 12.0 | 12.5 | 13.3 | 14.0 | 14.1 | 14.1 |
| | F2 | 4.2 | 5.0 | 6.1 | 7.3 | 8.2 | 9.8 | 10.8 | 11.8 | 12.5 | 13.5 | 14.4 | 15.2 | 15.2 |
| | F3 | 4.3 | 4.9 | 5.9 | 7.0 | 7.8 | 9.2 | 10.3 | 11.3 | 12.4 | 13.5 | 14.3 | 15.3 | 15.3 |
| | F4 | 4.2 | 4.8 | 5.3 | 6.0 | 6.8 | 8.1 | 9.4 | 10.6 | 11.7 | 12.9 | 14.1 | 14.9 | 15.6 |
| | NF | 5.1 | 6.1 | 7.4 | 8.5 | 9.2 | 9.9 | 10.5 | 11.1 | 11.7 | 12.6 | 12.9 | 12.9 | 12.9 |
| | CF | 5.8 | 7.4 | 8.9 | 10.2 | 10.9 | 11.8 | 12.6 | 13.1 | 13.6 | 14.5 | 15.1 | 15.1 | 15.1 |
| **Year** | **Treatment** | **12-May** | **19-May** | **26-May** | **2-Jun** | **9-Jun** | **16-Jun** | **23-Jun** | **30-Jun** | **7-Jul** | **14-Jul** | **21-Jul** | **28-Jul** | **4-Aug** |
| 2016 | S1 | 5.1 | 6.5 | 8.2 | 9.4 | 10.2 | 11.3 | 12.0 | 12.6 | 13.4 | 14.0 | 14.0 | 14.0 | 14.0 |
| | S2 | 5.0 | 6.3 | 7.9 | 9.1 | 10.2 | 11.3 | 12.1 | 12.7 | 13.6 | 14.3 | 14.3 | 14.3 | 14.3 |
| | S3 | 5.0 | 5.8 | 7.2 | 8.4 | 9.4 | 10.8 | 11.7 | 12.5 | 13.5 | 14.4 | 14.7 | 14.7 | 14.7 |
| | S4 | 4.6 | 5.2 | 6.5 | 7.7 | 9.1 | 10.5 | 11.5 | 12.3 | 13.3 | 14.2 | 14.9 | 14.9 | 14.9 |
| | F1 | 4.9 | 5.6 | 7.0 | 8.1 | 9.2 | 10.6 | 11.3 | 12.0 | 12.8 | 13.8 | 14.3 | 14.3 | 14.3 |
| | F2 | 4.5 | 5.0 | 6.1 | 7.2 | 8.4 | 9.8 | 10.9 | 11.6 | 12.6 | 13.6 | 14.3 | 14.3 | 14.3 |
| | F3 | 4.7 | 5.2 | 6.3 | 7.2 | 8.4 | 9.8 | 10.9 | 11.6 | 12.6 | 13.7 | 14.3 | 14.3 | 14.3 |
| | F4 | 4.5 | 5.0 | 5.8 | 6.6 | 7.7 | 9.0 | 10.3 | 11.1 | 12.3 | 13.2 | 14.1 | 14.3 | 14.3 |
| | NF | 4.7 | 6.0 | 7.4 | 8.8 | 9.6 | 10.7 | 11.4 | 12.0 | 12.9 | 13.3 | 13.3 | 13.3 | 13.3 |
| | CF | 5.2 | 6.7 | 8.7 | 10.0 | 10.8 | 12.0 | 12.7 | 13.3 | 14.2 | 14.8 | 15.0 | 15.0 | 15.0 |

**Plant length**

The means plant length of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 are shown in Fig. 1.4 and Fig. 1.5, respectively and Table 1.4.

Plant length of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$) in 2015 were found lower than control treatment CF until 12 WAT, afterward, plant length of treatment $S_4$ increased over control treatment CF. However, Control treatment NF (no fertilizer) recorded the lower plant length in comparison to SSC treatments during the all growth stages. At late growth stage (14 WAT) treatments $S_4$ recorded the higher plant length (116 cm), treatments $S_3$ and treatment CF were at par (114.8 and 114.2 cm, respectively), followed by treatment $S_2$ (105.7 cm) and the lower was found in treatment $S_1$ (97.3 cm) (Fig. 1.4). In 2016 the plant length of SSC treatments were found lower than control treatment CF until 11 WAT, afterward, plant length of all SSC treatments increased over control treatment CF except treatment $S_1$ which was lower than CF throughout the plant growth (Fig. 1.5).

Plant length of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) in 2015 were found significantly smaller than control treatment CF during the all growth stages. Treatment $F_1$ until 4 WAT, treatment $F_2$ until 8 WAT, treatment $F_3$ until 9 WAT and treatment $F_4$ until 10 WAT were even smaller than control treatment NF (no fertilizer). Among different FWC treatments plant length of treatment $F_4$ recorded the higher (104.5 cm), followed by treatment $F_2$ and $F_3$ (103.5 and 100.3, respectively) however, the minimum plant length was found in treatment $F_1$ (96.8 cm) at late growth stage (14 WAT) (Fig. 1.4). In 2016 plant length of FWC treatments were also found smaller than treatment CF throughout the plant growth. They were even recorded smaller than control treatment NF at initial growth stage however at the late growth stage plant length of FWC treatments were found higher than NF and lower than CF treatments (Fig. 1.5).

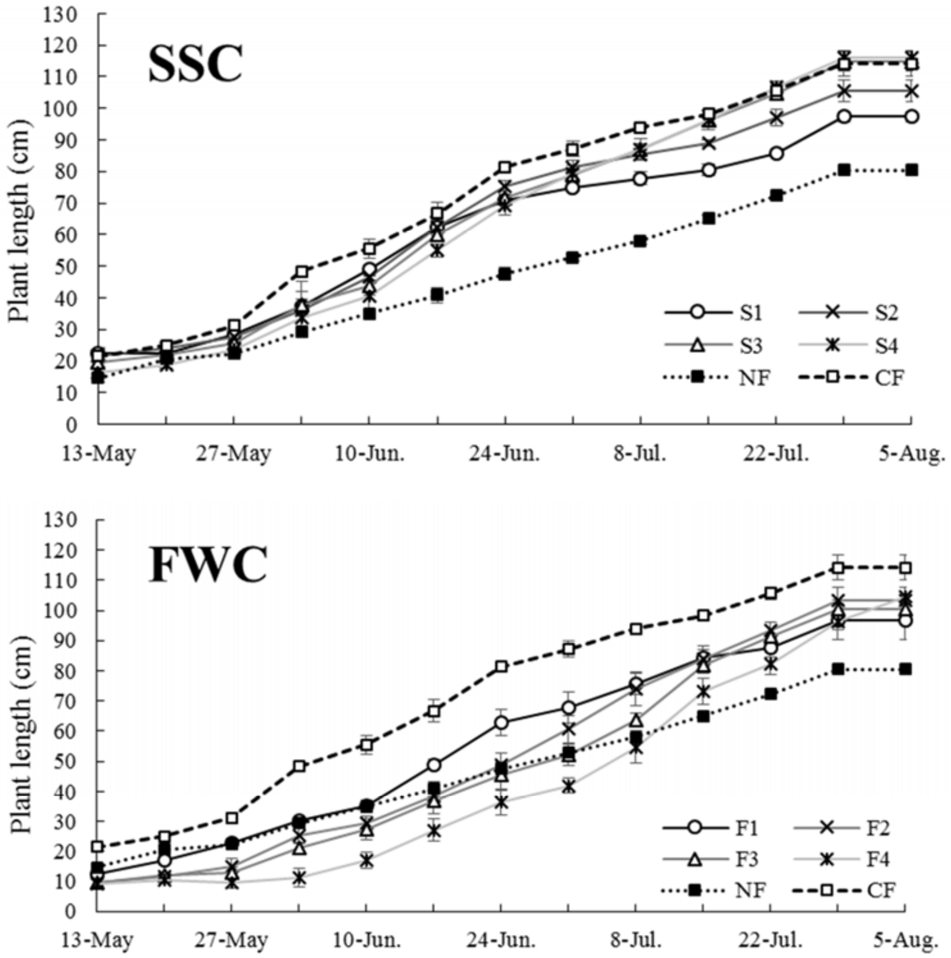



**Fig. 1.4. Effects of SSC and FWC treatments on plant length (cm) of rice plants in 2015.**

Data represent mean ± standard deviation (SD) (n = 3).

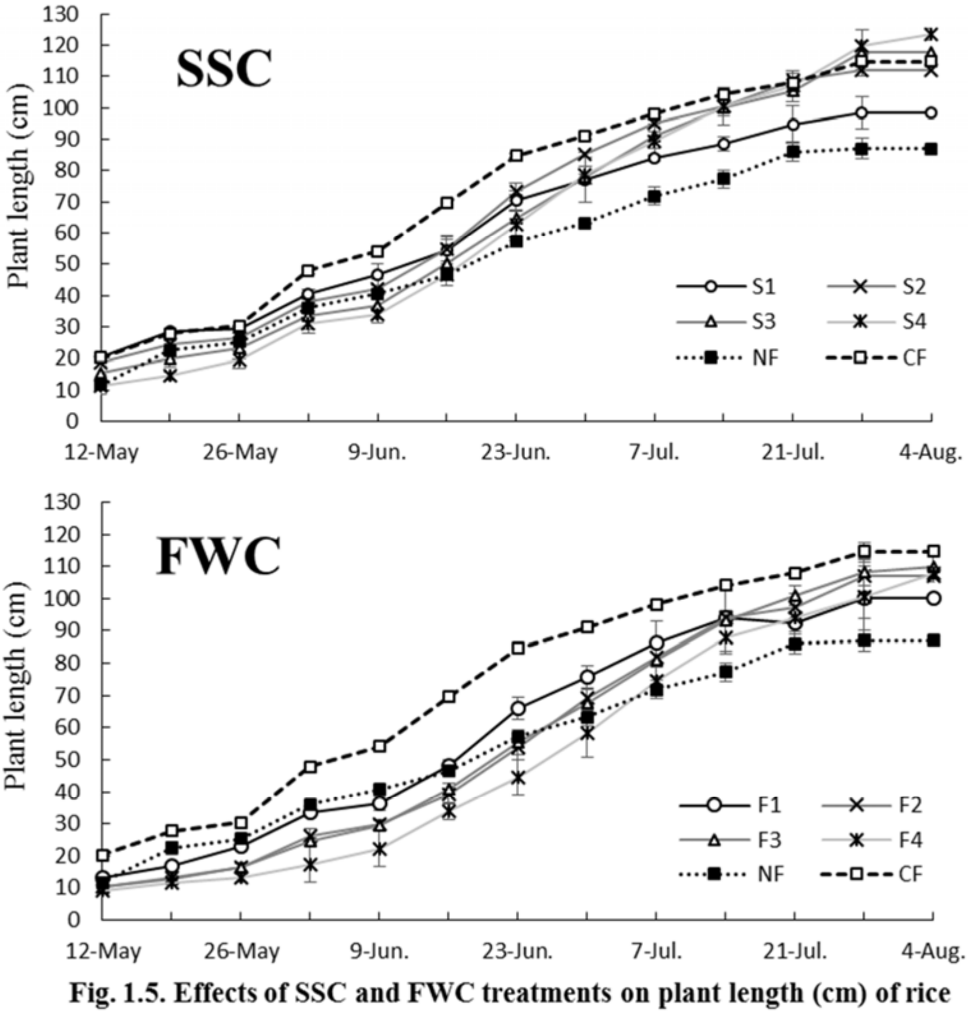



**Fig. 1.5. Effects of SSC and FWC treatments on plant length (cm) of rice plants in 2016.**

Data represent mean ± SD (n = 3).

**Table 1.4. Means of plant length (cm).**

| Year | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul | 29-Jul | 5-Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | S1 | 22.4 | 22.4 | 28.5 | 37.3 | 48.8 | 62.2 | 71.0 | 75.0 | 77.8 | 80.5 | 85.8 | 97.3 | 97.3 |
| | S2 | 21.7 | 23.9 | 27.6 | 36.1 | 46.7 | 62.3 | 75.3 | 81.3 | 85.3 | 89.0 | 97.0 | 105.7 | 105.7 |
| | S3 | 19.7 | 22.2 | 25.7 | 37.8 | 43.8 | 60.0 | 71.5 | 79.0 | 87.0 | 96.2 | 104.7 | 114.8 | 114.8 |
| | S4 | 16.3 | 18.8 | 23.7 | 33.6 | 40.7 | 55.0 | 69.3 | 79.3 | 87.2 | 96.3 | 106.7 | 116.0 | 116.0 |
| | F1 | 12.7 | 17.1 | 23.0 | 30.1 | 35.3 | 49.0 | 62.8 | 67.8 | 75.7 | 84.2 | 87.5 | 96.8 | 96.8 |
| | F2 | 9.6 | 11.5 | 14.8 | 25.3 | 29.3 | 38.5 | 48.8 | 60.7 | 74.0 | 83.8 | 93.5 | 103.5 | 103.5 |
| | F3 | 9.6 | 12.0 | 13.1 | 21.1 | 27.3 | 36.7 | 45.3 | 52.0 | 63.8 | 81.8 | 91.3 | 100.3 | 100.3 |
| | F4 | 9.1 | 10.3 | 9.5 | 11.3 | 17.0 | 27.2 | 36.3 | 42.0 | 54.7 | 73.2 | 82.3 | 96.5 | 104.5 |
| | NF | 14.6 | 20.7 | 22.3 | 29.3 | 35.0 | 40.8 | 47.5 | 52.8 | 58.0 | 65.0 | 72.3 | 80.5 | 80.5 |
| | CF | 21.4 | 24.9 | 31.2 | 48.4 | 55.5 | 66.7 | 81.3 | 87.2 | 94.0 | 98.2 | 105.7 | 114.2 | 114.2 |
| **Year** | **Treatment** | **12-May** | **19-May** | **26-May** | **2-Jun** | **9-Jun** | **16-Jun** | **23-Jun** | **30-Jun** | **7-Jul** | **14-Jul** | **21-Jul** | **28-Jul** | **4-Aug** |
| 2016 | S1 | 20.4 | 28.5 | 29.3 | 40.3 | 46.7 | 54.5 | 70.3 | 77.2 | 83.8 | 88.5 | 94.7 | 98.5 | 98.5 |
| | S2 | 18.6 | 24.4 | 26.5 | 38.2 | 42.2 | 54.7 | 73.2 | 85.2 | 95.0 | 100.5 | 108.5 | 112.0 | 112.0 |
| | S3 | 15.3 | 20.0 | 23.2 | 33.3 | 36.8 | 50.3 | 64.8 | 77.8 | 91.0 | 100.2 | 105.3 | 117.5 | 117.5 |
| | S4 | 11.1 | 14.4 | 19.4 | 31.0 | 33.7 | 46.7 | 62.7 | 78.7 | 89.3 | 100.5 | 106.8 | 119.7 | 123.5 |
| | F1 | 13.1 | 16.8 | 22.8 | 33.5 | 36.5 | 48.2 | 66.0 | 75.8 | 86.3 | 94.2 | 92.3 | 100.2 | 100.2 |
| | F2 | 10.4 | 13.3 | 16.3 | 26.2 | 29.7 | 39.3 | 54.0 | 69.3 | 81.8 | 93.8 | 97.3 | 107.0 | 107.0 |
| | F3 | 10.2 | 12.8 | 16.3 | 24.7 | 29.5 | 40.8 | 55.3 | 67.8 | 81.2 | 93.2 | 101.0 | 108.2 | 110.0 |
| | F4 | 9.1 | 11.8 | 13.1 | 17.4 | 22.2 | 33.8 | 44.3 | 58.2 | 74.5 | 88.0 | 93.8 | 100.5 | 107.7 |
| | NF | 11.7 | 22.4 | 25.2 | 36.0 | 40.6 | 46.5 | 57.2 | 63.2 | 71.8 | 77.3 | 86.0 | 87.0 | 87.0 |
| | CF | 20.2 | 27.8 | 30.3 | 47.9 | 54.2 | 69.5 | 84.7 | 91.0 | 98.2 | 104.2 | 108.0 | 114.7 | 114.7 |

**Tiller number**

The means tiller number of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 are shown in Fig. 1.6 and Fig. 1.7, respectively and Table 1.5.

In 2015, Tiller numbers of treatments $S_1$, $S_2$ $S_3$ and $S_4$ were decreased by increasing level of compost at early growth stage (1-6 WAT), the maximum was found in treatment $S_1$ (31.5) and the minimum was recorded in treatment $S_4$ (14.3) at 6 WAT. However at the late growth stage tiller number of SSC treatments conversely increased by increasing level of compost, the maximum was registered in treatment $S_4$ (42.3), followed by treatments $S_2$ and $S_3$ (35.7 and 34.2 respectively) and the minimum was counted in treatment $S_1$ (29.2). Tiller number of control treatment CF was higher than all other treatments during the early and late growth stages (38 and 47.8 respectively). However, control treatment NF (no fertilizer) recorded the lowest mean tiller number during the early and late growth stages. (8 and 5.7 respectively) (Fig. 1.6).

In 2016, tiller number of SSC treatments ($S_1$, $S_2$ $S_3$ and $S_4$) were also recorded significantly lower than treatment CF throughout the plant growth. Treatments $S_3$ and $S_4$ were found even lower than NF until 7 WAT and lower than treatments $S_1$ and $S_2$ until 11 and 12 WAT, respectively. Afterward, they increased by increasing the level of SSC (Fig. 1.7).

The tiller number of FWC treatments $F_1$, $F_2$, $F_3$ and $F_4$ in 2015 were found significantly smaller than control treatment CF at the early and late growth stages ($p<0.05$). Tiller number of treatments $F_2$, $F_3$ and $F_4$ (4.8, 3 and 2 respectively) were even smaller than control treatment NF (8) until 6 WAT. Afterward, tiller numbers of FWC treatments increased at the late stage by increasing their levels, the maximum was recorded in treatment $F_3$ (25.5) which was at par with $F_4$ (24.7), followed by $F_2$ (22.7) and the minimum was found in treatment $F_1$ (19.2) (Fig. 1.6). The means tiller number of FWC treatments in 2016 also found significantly smaller than treatment CF throughout the plant growth, they were even smaller than NF until 7 WAT for treatment $F_1$, until 10 WAT for treatments $F_2$ and $F_3$, and until 11 WAT for treatments $F_4$. Afterward, treatment $F_3$ recorded higher tiller number than rest of FWC treatments at late growth stage (14 WAT) (Fig. 1.7).

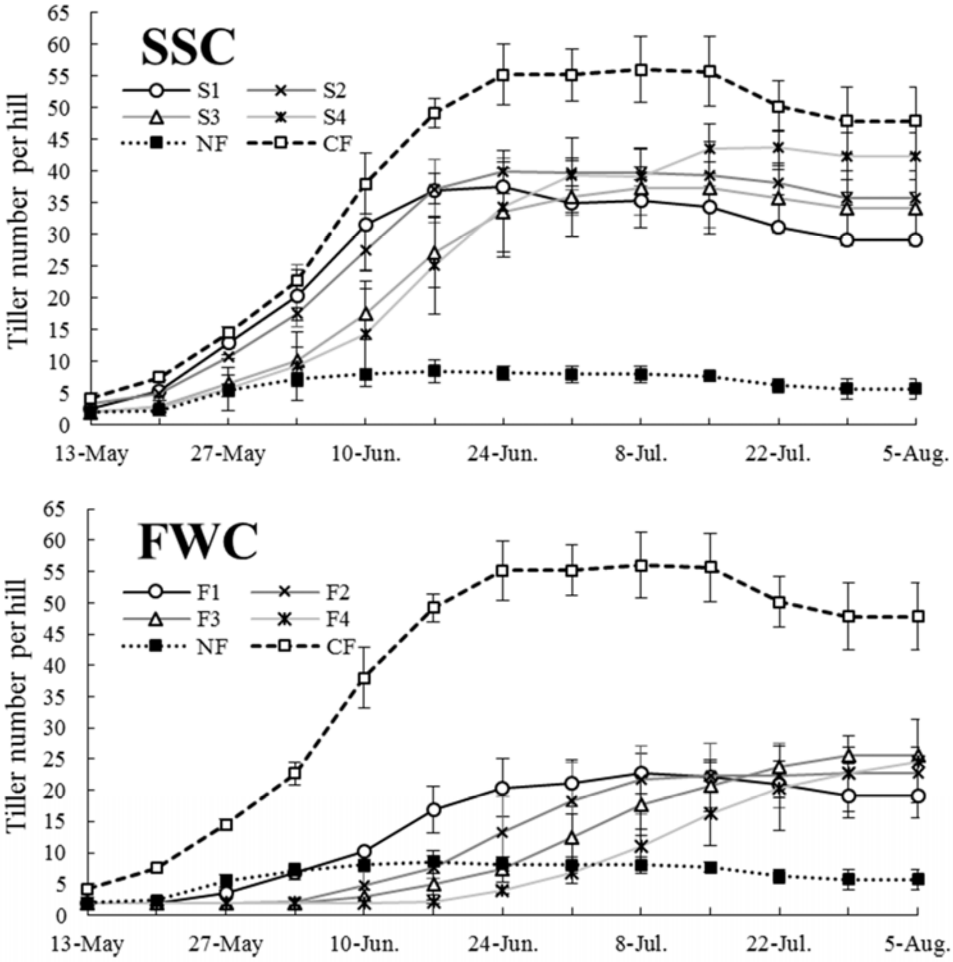



**Fig. 1.6. Effects of SSC and FWC treatments on the tiller number of rice plants in 2015.**

Data represent mean ± standard deviation (SD) (n = 3).

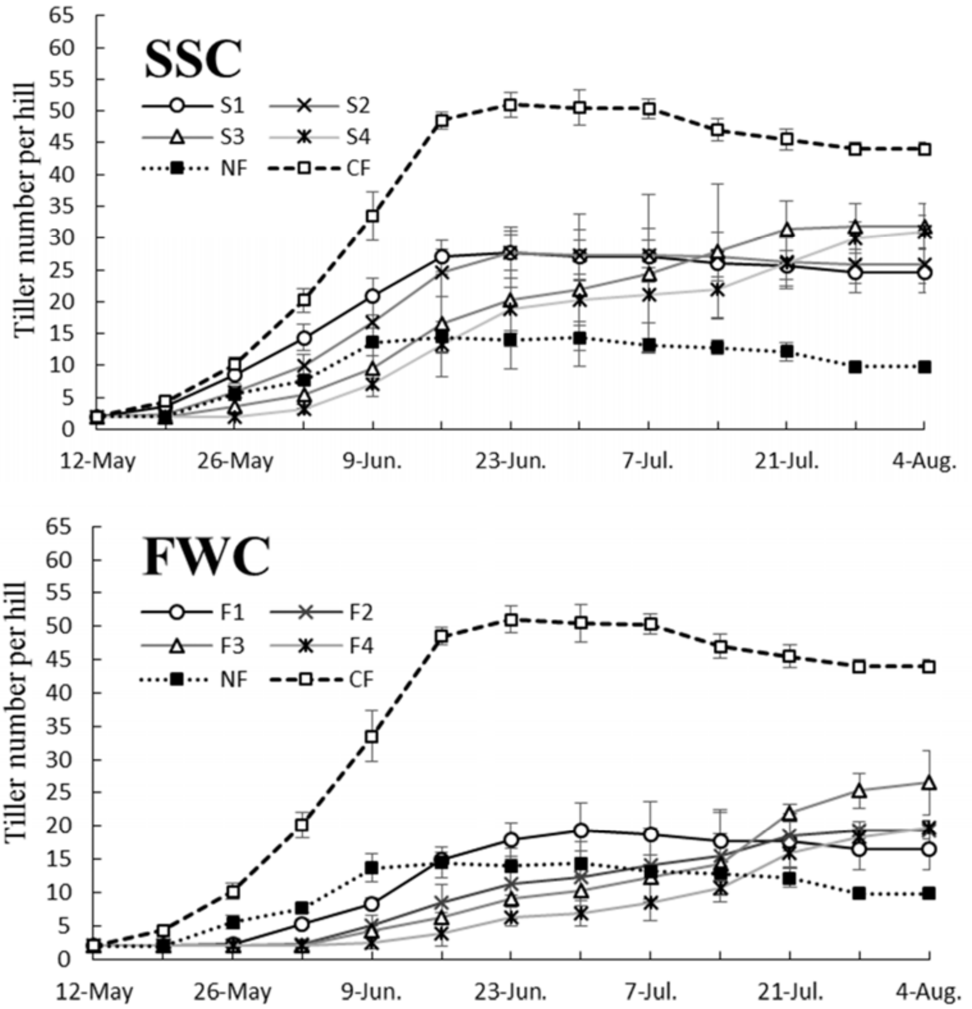



**Fig. 1.7. Effects of SSC and FWC treatments on the tiller number of rice plants in 2016.**

Data represent mean ± SD (n = 3).

**Table 1.5. Means of tillers number.**

| Year | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul | 29-Jul | 5-Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | S1 | 2.5 | 5.3 | 13.0 | 20.3 | 31.5 | 36.8 | 37.5 | 35.0 | 35.3 | 34.3 | 31.2 | 29.2 | 29.2 |
| | S2 | 3.3 | 5.0 | 10.8 | 17.5 | 27.5 | 37.2 | 39.8 | 39.7 | 39.7 | 39.3 | 38.2 | 35.7 | 35.7 |
| | S3 | 2.0 | 3.0 | 6.5 | 10.2 | 17.5 | 27.2 | 33.5 | 35.8 | 37.3 | 37.3 | 35.7 | 34.2 | 34.2 |
| | S4 | 2.2 | 2.7 | 5.7 | 9.3 | 14.3 | 25.2 | 34.3 | 39.3 | 39.2 | 43.5 | 43.7 | 42.3 | 42.3 |
| | F1 | 2.0 | 2.0 | 3.5 | 6.8 | 10.2 | 16.8 | 20.3 | 21.2 | 22.7 | 22.2 | 20.8 | 19.2 | 19.2 |
| | F2 | 2.0 | 2.0 | 2.0 | 2.2 | 4.8 | 7.7 | 13.2 | 18.3 | 21.7 | 22.3 | 22.3 | 22.7 | 22.7 |
| | F3 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 5.0 | 7.3 | 12.3 | 17.7 | 20.7 | 23.8 | 25.5 | 25.5 |
| | F4 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.2 | 4.0 | 6.7 | 11.0 | 16.3 | 20.3 | 22.7 | 24.7 |
| | NF | 2.0 | 2.3 | 5.5 | 7.2 | 8.0 | 8.5 | 8.2 | 8.0 | 8.0 | 7.7 | 6.2 | 5.7 | 5.7 |
| | CF | 4.2 | 7.5 | 14.5 | 22.7 | 38.0 | 49.2 | 55.2 | 55.2 | 56.0 | 55.7 | 50.2 | 47.8 | 47.8 |
| **Year** | **Treatment** | **12-May** | **19-May** | **26-May** | **2-Jun** | **9-Jun** | **16-Jun** | **23-Jun** | **30-Jun** | **7-Jul** | **14-Jul** | **21-Jul** | **28-Jul** | **4-Aug** |
| 2016 | S1 | 2.0 | 3.5 | 8.5 | 14.3 | 20.8 | 27.0 | 27.7 | 27.0 | 27.0 | 26.0 | 25.7 | 24.7 | 24.7 |
| | S2 | 2.0 | 2.3 | 5.8 | 10.0 | 16.7 | 24.5 | 27.7 | 27.3 | 27.3 | 27.0 | 26.2 | 25.8 | 25.8 |
| | S3 | 2.0 | 2.0 | 3.5 | 5.5 | 9.5 | 16.5 | 20.3 | 21.8 | 24.3 | 27.8 | 31.3 | 31.8 | 31.8 |
| | S4 | 2.0 | 2.0 | 2.0 | 3.2 | 7.2 | 13.3 | 18.8 | 20.2 | 21.0 | 22.0 | 26.0 | 30.0 | 31.0 |
| | F1 | 2.0 | 2.0 | 2.3 | 5.3 | 8.3 | 14.8 | 18.0 | 19.3 | 18.8 | 17.8 | 17.8 | 16.5 | 16.5 |
| | F2 | 2.0 | 2.0 | 2.0 | 2.3 | 5.0 | 8.5 | 11.3 | 12.3 | 14.2 | 15.5 | 18.5 | 19.3 | 19.3 |
| | F3 | 2.0 | 2.0 | 2.0 | 2.0 | 4.2 | 6.3 | 9.0 | 10.3 | 12.3 | 14.3 | 22.0 | 25.3 | 26.5 |
| | F4 | 2.0 | 2.0 | 2.0 | 2.0 | 2.5 | 3.8 | 6.3 | 6.8 | 8.5 | 10.7 | 16.0 | 18.3 | 19.8 |
| | NF | 2.0 | 2.0 | 5.5 | 7.7 | 13.7 | 14.5 | 14.0 | 14.3 | 13.2 | 12.8 | 12.2 | 9.8 | 9.8 |
| | CF | 2.0 | 4.3 | 10.2 | 20.2 | 33.5 | 48.5 | 51.0 | 50.5 | 50.3 | 47.0 | 45.5 | 44.0 | 44.0 |

Leaf emergence pattern, plant length and tiller number of SSC and FWC treatments were significantly influenced by different compost types and levels, their inclination and tendency was same in 2015 and 2016. Leaf emergence pattern, plant length and tiller number were decreased and inhibited by increasing level of compost at initial growth stag. However, at the late growth stage they were conversely increased by increasing level of compost. The application of SSC was more effective on leaf emergence pattern, plant length and tiller number and was performed better than FWC.

**Heading stage and maturity stage**

Table 1.6 shows the days of heading stage and maturity stage in 2015 and 2016. SSC and FWC with their levels influenced the duration from transplanting to heading stage and heading stage to maturity stage.

In 2015, the minimum duration from transplanting to heading stage among SSC treatments was found in treatment $S_1$ (86 days), it was followed by treatments $S_2$ and $S_3$ (89 and 91 days, respectively) and the maximum was found in treatment $S_4$ (95 days). Meanwhile, the duration from transplanting to heading stage in FWC treatments was recorded minimum in treatment $F_1$ (86 days), followed by treatments $F_2$ and $F_3$ (96 and 97 days, respectively) and the maximum was found in treatment $F_4$ (103 days). Except for treatments $S_1$ and $S_2$ the duration between transplanting to heading stage of all other SSC and FWC treatments were found longer than control treatment CF and NF (91 and 90 days, respectively). In 2016, the duration from transplanting to heading stage of SSC and FWC treatments elongated by increasing their levels, the maximum days was recorded in treatment $S_4$ and $F_4$ (94 and 101 days, respectively) however, the shorter duration from transplanting to heading stage was found in treatments $S_1$ and $F_1$ (83 and 86 days, respectively) (Table 1.6).

Date of maturity of SSC treatments was longer in treatment $S_4$ (9 Sep. in 2015 and 7 Sep. in 2016), followed by treatment $S_3$ (3 Sep. in 2015 and 4 Sep. in 2016), however date of maturity was shorter in treatment $S_1$ (31 Aug. in 2015 and 30 Aug. in 2016) which was at par with treatment $S_2$ (31 Aug. in 2015 and 2016). Meanwhile, Date of maturity of FWC treatments was longer in treatment $F_4$ (17 Sep. in 2015 and 9 Sep. in 2016), followed by treatment $F_3$ (12 Sep. in 2015 and 6 Sep. in 2016) and treatment $F_2$ (9 Sep. in 2015 and 5 Sep. in 2016) however, date of maturity was shorter in treatment $F_1$ (4 Sep. in 2015 and 31 Aug. in 2016). Except treatments $S_1$ and $S_2$ the maturity date of all other SSC and FWC treatments were found longer than control treatment CF and NF (1 Sep. and 3 Sep. in 2015, respectively; 31 Aug. and 29 Aug. in 2016, respectively) (Table 1.6).

The period from transplantation to maturity was prolonged with the increase in the N levels of the compost. The $F_4$ treatment was the last to be harvested, signifying a delay of about 16 and 9 days than the CF treatment in 2015 and 2016, respectively. Though, days from the transplanting to heading stage and the ripening period became longer than CF treatment as the amount of compost application increased, using either SSC or FWC.

**Table 1.6. Days to heading and maturity of rice plants in 2015 and 2016.**

| Treatments | 2015 | | 2016 | |
|---|---|---|---|---|
| | Heading stage* | Maturity stage** | Heading stage* | Maturity stage** |
| $S_1$ | 24-Jul (86) | 31-Aug (38) | 21-Jul (83) | 30-Aug (40) |
| $S_2$ | 27-Jul (89) | 31-Aug (35) | 22-Jul (84) | 31-Aug (40) |
| $S_3$ | 29-Jul (91) | 3-Sep (36) | 27-Jul (89) | 4-Sep (39) |
| $S_4$ | 2-Aug (95) | 9-Sep (38) | 1-Aug (94) | 7-Sep (37) |
| $F_1$ | 30-Jul (92) | 4-Sep (36) | 24-Jul (86) | 31-Aug (38) |
| $F_2$ | 3-Aug (96) | 9-Sep (37) | 31-Jul (93) | 5-Sep (36) |
| $F_3$ | 4-Aug (97) | 12-Sep (39) | 6-Aug (99) | 6-Sep (31) |
| $F_4$ | 10-Aug (103) | 17-Sep (38) | 8-Aug (101) | 9-Sep (32) |
| CF | 29-Jul (91) | 1-Sep (34) | 25-Jul (87) | 31-Aug (37) |
| NF | 28-Jul (90) | 3-Sep (37) | 21-Jul (83) | 29-Aug (39) |

*Data shown in parentheses are days from transplanting to heading stage.
**Data shown in parentheses are days of ripening period from heading to maturity stage.

**Soil pH**

The changes in submerged soil pH in each treatment from one WAT in 2015 and two WAT in 2016 to 6 WAT and 7 WAT, respectively are shown in Table 1.7. The soil pH at 6 WAT and 7 WAT was influenced by different levels of SSC and FWC treatments and CF in 2015 and 2016, respectively. The soil pH values of SSC and FWC treatments were close to neutral and increased numerically by increasing their levels. In 2015, treatments $S_4$ and $F_4$ (6.32 and 6.50, respectively) had highest pH value among the levels of SSC and FWC, while $S_1$ and $F_1$ were lower (6.04 and 6.18, respectively). In second year (2016), similar trend was recorded, $S_4$ and $F_4$ had the highest value (6.07 and 6.23, respectively), while the least were in treatments $S_1$ and $F_1$ (5.84 and 6.08, respectively). However, in comparison to CF treatments the soil pH of treatment CF was least than SSC and FWC treatments in 2015 and 2016 (5.83 and 5.78, respectively).

**Table 1.7. Means of soil pH.**

| Year | Treatment | 8-May | 15-May | 22-May | 29-May | 5-Jun | 12-Jun |
|---|---|---|---|---|---|---|---|
| 2015 | **S1** | 6.28 | 6.21 | 6.12 | 5.98 | 6.62 | 6.46 |
| | **S2** | 6.60 | 6.67 | 6.41 | 5.99 | 6.42 | 6.36 |
| | **S3** | 6.58 | 6.82 | 6.89 | 6.21 | 6.63 | 6.47 |
| | **S4** | 6.75 | 7.36 | 7.07 | 6.24 | 6.78 | 6.60 |
| | **F1** | 6.54 | 6.57 | 6.35 | 6.05 | 6.40 | 6.30 |
| | **F2** | 6.75 | 6.86 | 6.47 | 6.07 | 6.52 | 6.39 |
| | **F3** | 6.79 | 6.83 | 6.77 | 6.02 | 6.62 | 6.46 |
| | **F4** | 6.57 | 6.57 | 6.54 | 6.10 | 6.59 | 6.52 |
| | **NF** | 6.28 | 6.51 | 6.32 | 5.96 | 6.31 | 6.32 |
| | **CF** | 4.92 | 5.04 | 4.79 | 4.44 | 4.97 | 5.28 |
| **Year** | **Treatment** | **13-May** | **20-May** | **27-May** | **3-Jun** | **10-Jun** | **17-Jun** |
| 2016 | **S1** | 6.72 | 6.16 | 6.30 | 6.01 | 5.95 | 5.84 |
| | **S2** | 6.39 | 6.24 | 6.28 | 6.14 | 5.99 | 5.94 |
| | **S3** | 6.32 | 6.34 | 6.42 | 6.29 | 6.27 | 5.98 |
| | **S4** | 6.38 | 6.28 | 6.55 | 6.38 | 6.32 | 6.07 |
| | **F1** | 6.45 | 6.23 | 6.45 | 6.24 | 6.12 | 6.08 |
| | **F2** | 6.46 | 6.35 | 6.48 | 6.23 | 6.17 | 6.14 |
| | **F3** | 6.33 | 6.36 | 6.43 | 6.31 | 6.18 | 6.18 |
| | **F4** | 6.38 | 6.32 | 6.41 | 6.35 | 6.27 | 6.23 |
| | **NF** | 6.67 | 5.69 | 5.99 | 5.92 | 5.71 | 5.78 |
| | **CF** | 5.14 | 5.06 | 5.26 | 4.80 | 5.12 | 5.11 |

**Soil-plant analysis development (SPAD) value**

Table 1.8 indicates the SPAD values of uppermost 3 leaves (flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf) of SSC, FWC, CF and no fertilizer (NF) treatments in 2015 and 2016. SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf were obviously differ among different composts (SSC and FWC) and their levels at heading stage and 10 days after heading stage.

At heading stage in 2015, the greater SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf were observed in high level of SSC treatment $S_4$ (42.5, 44.8 and 44.8 respectively) and FWC treatment $F_4$ (45.3, 46.1 and 45.3, respectively) and the lowest was recorded in low level of SSC treatment $S_1$ (33.9, 34.2 and 31.9, respectively) and FWC treatment $F_1$ (31.9, 32.7 and 31.9 respectively). However, control treatment CF recorded lower SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf (39.2, 40.9 and 41.5, respectively) in comparison to treatments $S_4$, $S_3$, $F_4$ and $F_3$ at heading stage.

At 10 days after heading stage in 2015, the greater SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf were also observed in SSC treatments $S_4$ (41.5, 43.0 and 40.9, respectively) and FWC treatments $F_4$ (43.9, 42.9 and 35.4, respectively) and the lowest were recorded in SSC treatments $S_1$ (27.7, 22.2 and 18.5, respectively) and FWC treatments $F_1$ (28.8, 25.8 and 21.4 respectively), however, control treatment CF recorded lower SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf (34.4, 33.4 and 33.0, respectively) in comparison to treatments $S_4$, $S_3$, $F_4$, $F_3$, and $F_2$ at 10 days after heading stage.

At 20 days after heading stage in 2015, the mean SPAD values of flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf shown the same trend as heading stage and 10 days after heading stage, but the mean

SPAD values of flag leaf, 2nd leaf and 3rd at 20 days after heading stage were lower than heading stage and 10 days after heading stage (Table 1.8).

In 2016, the SPAD values of flag leaf, 2nd leaf and 3rd leaf of heading stage, 10 days after heading stage and 20 days after heading stage of SSC and FWC treatments also increased by increasing levels of SSC and FWC. The maximum was recorded in treatments $S_4$ and $F_4$ and the lower was found in treatments $S_1$ and $F_1$. The SPAD values of treatments $S_4$ and $F_4$ were recorded higher than control treatment CF (Table 1.8).

The SPAD values of flag leaf, 2nd leaf and 3rd leaf at heading stage, 10 days after heading stage and 20 days after heading stage indicated the same inclination and tendency in 2015 and 2016. High level of SSC and FWC recorded higher SPAD values. The SPAD values of heading stage registered higher than 10 days after heading stage. As well, the SPAD values of 10 days after heading stage recorded higher than 20 days after heading stage. Therefore, it is signify that the SPAD values of uppermost three leaves decreased in 10 days and more reduced in 20 days after heading stage.

**Table 1.8. Soil-plant analysis development (SPAD) values in 2015 and 2016.**

| Years | Trea-tments | Heading Stage | | | 10 days after Heading stage | | | 20 days after heading stage | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Flag leaf ± SD | Second leaf ± SD | Third leaf ± SD | Flag leaf ± SD | Second leaf ± SD | Third leaf ± SD | Flag leaf ± SD | Second leaf ± SD | Third leaf ± SD |
| 2015 | **S1** | 33.9 ± 0.9 | 34.2 ± 0.2 | 31.9 ± 0.5 | 27.7 ± 0.8 | 22.2 ± 0.7 | 18.5 ± 2.4 | 21.3 ± 1.2 | 16.6 ± 1.8 | 17.2 ± 0.4 |
| | **S2** | 37.2 ± 0.4 | 38.7 ± 0.9 | 37.1 ± 1.1 | 34.6 ± 0.4 | 32.1 ± 1.1 | 22.4 ± 5.9 | 27.2 ± 1.7 | 23.2 ± 2.4 | 21.6 ± 1.2 |
| | **S3** | 40.9 ± 1.8 | 43.6 ± 1.9 | 44.8 ± 2.1 | 40.3 ± 0.4 | 40.3 ± 1.9 | 37.9 ± 4.2 | 32.3 ± 1.0 | 29.4 ± 2.1 | 30.2 ± 4.6 |
| | **S4** | 42.5 ± 4.1 | 44.9 ± 2.0 | 44.8 ± 2.1 | 41.5 ± 2.1 | 43.0 ± 2.9 | 40.9 ± 1.9 | 38.0 ± 2.0 | 35.4 ± 2.9 | 32.0 ± 5.3 |
| | **F1** | 31.9 ± 0.9 | 32.7 ± 2.0 | 31.9 ± 3.0 | 28.8 ± 0.8 | 25.8 ± 4.3 | 21.4 ± 2.4 | 22.2 ± 3.2 | 18.4 ± 2.4 | 18.4 ± 3.7 |
| | **F2** | 35.6 ± 2.5 | 38.1 ± 2.9 | 35.4 ± 2.2 | 35.4 ± 1.9 | 39.4 ± 2.9 | 34.6 ± 6.6 | 27.1 ± 4.5 | 25.0 ± 4.8 | 20.5 ± 3.8 |
| | **F3** | 43.5 ± 3.1 | 44.5 ± 0.3 | 43.1 ± 1.2 | 43.9 ± 3.4 | 44.8 ± 1.8 | 43.5 ± 2.0 | 37.1 ± 2.3 | 37.2 ± 5.3 | 33.1 ± 1.0 |
| | **F4** | 45.3 ± 0.9 | 46.1 ± 1.1 | 45.3 ± 0.5 | 43.9 ± 1.2 | 42.9 ± 2.8 | 35.4 ± 11.5 | 42.5 ± 2.6 | 41.1 ± 4.4 | 38.3 ± 5.3 |
| | **NF** | 31.7 ± 1.4 | 28.7 ± 2.3 | 21.9 ± 5.6 | 30.3 ± 3.6 | 25.5 ± 3.7 | 22.3 ± 3.4 | 27.2 ± 5.0 | 21.3 ± 5.1 | 21.2 ± 5.8 |
| | **CF** | 39.2 ± 1.4 | 40.9 ± 0.5 | 41.5 ± 0.6 | 34.4 ± 1.5 | 33.4 ± 2.3 | 33.0 ± 2.6 | 28.5 ± 2.0 | 26.3 ± 0.2 | - ± - |
| 2016 | **S1** | 28.3 ± 2.8 | 29.5 ± 2.3 | 29.4 ± 3.0 | 36.2 ± 2.6 | 34.4 ± 1.5 | 29.2 ± 3.2 | 17.3 ± 3.1 | 12.2 ± 2.0 | 13.9 ± 0.5 |
| | **S2** | 41.5 ± 1.8 | 43.9 ± 0.9 | 43.8 ± 2.5 | 41.8 ± 1.6 | 41.2 ± 2.6 | 37.9 ± 3.7 | 24.7 ± 2.3 | 16.0 ± 2.0 | - ± - |
| | **S3** | 46.0 ± 3.7 | 48.7 ± 3.6 | 46.7 ± 2.9 | 45.0 ± 4.4 | 45.3 ± 5.0 | 41.5 ± 7.0 | 31.7 ± 5.1 | 24.3 ± 2.5 | - ± - |
| | **S4** | 46.3 ± 2.5 | 46.7 ± 2.2 | 45.4 ± 2.6 | 44.7 ± 2.2 | 47.4 ± 3.6 | 44.4 ± 4.2 | 34.9 ± 5.9 | 34.3 ± 3.6 | 30.4 ± 5.5 |
| | **F1** | 32.6 ± 2.9 | 34.0 ± 3.6 | 33.4 ± 5.4 | 31.4 ± 2.2 | 29.8 ± 3.2 | 26.9 ± 3.8 | 16.0 ± 3.1 | 13.6 ± 1.0 | - ± - |
| | **F2** | 40.2 ± 3.2 | 41.5 ± 2.5 | 40.6 ± 2.2 | 37.5 ± 3.4 | 35.8 ± 4.1 | 32.4 ± 3.3 | 20.2 ± 2.1 | 15.1 ± 2.1 | 14.3 ± 0.4 |
| | **F3** | 43.5 ± 1.8 | 43.8 ± 1.6 | 41.3 ± 0.8 | 36.2 ± 5.8 | 32.6 ± 5.0 | 27.2 ± 4.8 | 22.1 ± 4.4 | 18.0 ± 1.8 | - ± - |
| | **F4** | 46.8 ± 1.8 | 44.4 ± 0.5 | 43.0 ± 0.6 | 43.4 ± 2.0 | 41.4 ± 1.8 | 39.1 ± 1.1 | 33.2 ± 2.6 | 28.6 ± 3.5 | 24.7 ± 1.9 |
| | **NF** | 29.9 ± 0.5 | 28.4 ± 1.8 | 25.4 ± 2.0 | 28.6 ± 1.8 | 24.0 ± 3.5 | 20.1 ± 3.6 | 18.4 ± 2.2 | 10.8 ± 3.6 | 12.2 ± 1.1 |
| | **CF** | 38.5 ± 0.2 | 41.9 ± 1.3 | 41.4 ± 0.8 | 39.3 ± 0.6 | 39.6 ± 1.2 | 32.8 ± 2.7 | 22.7 ± 1.6 | - ± - | - ± - |

- means no data due to over 80% of the leaf died. SD = Standard deviation (n=3).

**Effects on yield components**

It was found from the result of this study that application of SSC and FWC with their levels obviously effect on yield components of rice. Top air-dry weight, weight of winnowed rough rice, straw weight, number of productive panicle, average number of spikelet per panicle, percentage of ripened grains, 1000-winnowed rough rice weigh, culm length, panicle length, internodes length, maximum tiller number per hill, number of grain per panicle and percentage of productive culms were differ by different composts (SSC and FWC) and their levels. In general, yield components of SSC treatments were performed better than FWC treatments.

**Top air-dry weight per hill (g)**

Top air-dry weight per hill of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 indicated in Table 1.9 and Table 1.10, respectively.

Top air-dry weight was obviously differ among different types of compost (SSC and FWC) and their levels in 2015 and 2016. It was increased with the increase in the amount of compost applied in SSC treatments. Among the FWC treatments, the top air-dry weight of rice plants was the highest with the F3 treatment. The maximum top air-dry weight of SSC treatments in 2015 was registered in treatment $S_4$ (156.1 g) which was at par with treatment $S_3$ (132.7 g), followed by treatments $S_2$ (110.8 g) and the minimum was counted in treatment $S_1$ (77.5 g). However, control treatment CF was found higher (135.3 g) than treatments $S_1$ and $S_2$ but at par with treatment $S_3$ and $S_4$ (Table 1.9). In 2016, treatments S1, S2 and S3 were found at par with each other however, the significantly minimum was recorded in treatment S1. All SSC and FWC treatments registered lower top air-dry weight in comparison to control treatment CF (Table 1.10).

The top air-dry weight of FWC treatments in 2015 was recorded higher in treatment $F_3$ (111.8 g), followed by treatments $F_4$ and $F_2$ (98.6 and 84.3 g, respectively) and the lower was registered in treatment $F_1$ (58.9 g). All FWC treatments were recorded lower top air-dry weight in contrast with control treatment CF (135.3) (Table 1.9). The top air-dry weight in 2016 did not significantly differ among different FWC treatments but all treatments were found lower than control treatments CF (Table 1.10).

**Table 1.9 Measurements of yield parameters of rice plants in 2015.**

| Treatment | Top air-dry weight per hill (g) | Yield (winnowed rough rice) per hill (dry weight, g) | Number of productive panicles per hill | Average Number of spikelets per panicle | Percentage of ripened grains (%) | 1000-winnowed rough rice (dry weight, g) | Culm length (cm) | Panicle length (cm) | Maximum tiller number per hill | Percentage of productive culms (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **$S_1$** | 77.5 b | 29.2 bc | 24.0 bc | 66.2 ab | 81.7 bc | 22.6 bcd | 75.5 b | 18.2 a | 37.7 c | 64.5 a |
| **$S_2$** | 110.8 cd | 44.6 de | 33.0 cd | 76.6 abc | 84.0 bc | 20.9 ab | 80.1 bc | 18.4 a | 40.7 c | 81.3 bc |
| **$S_3$** | 132.7 de | 52.8 de | 32.3 cd | 100.3 cd | 78.4 bc | 21.1 ab | 86.3 cd | 19.7 ab | 37.7 c | 86.1 bc |
| **$S_4$** | 156.1 e | 57.6 e | 38.5 d | 100.5 cd | 73.3 b | 20.5 a | 89.7 d | 20.0 ab | 44.3 c | 85.8 bc |
| **$F_1$** | 58.9 b | 22.8 b | 15.8 b | 85.7 bc | 76.7 bc | 21.8 abc | 74.9 b | 18.3 a | 23.0 b | 68.8 ab |
| **$F_2$** | 84.3 bc | 38.5 cd | 21.3 b | 100.4 cd | 79.7 bc | 23.0 cd | 80.2 bc | 20.2 ab | 23.0 b | 93.3 bc |
| **$F_3$** | 111.8 cd | 52.0 de | 24.7 bc | 117.9 d | 75.4 b | 23.5 d | 82.1 bc | 23.1 c | 25.5 b | 97.2 c |
| **$F_4$** | 98.6 c | 41.1 cde | 23.3 b | 107.4 d | 69.8 ab | 23.8 d | 84.6 cd | 21.4 bc | 24.8 b | 94.3 bc |
| **CF** | 135.3 de | 38.4 cd | 39.5 d | 84.6 abc | 57.4 a | 20.1 a | 86.0 cd | 19.3 ab | 56.8 d | 69.9 ab |
| **NF** | 16.6 a | 6.4 a | 5.3 a | 60.8 a | 85.9 c | 23.1 cd | 60.2 a | 17.5 a | 8.7 a | 61.7 a |

Means within each column with the same letter(s) are not significantly different at $P<0.05$.

**Table 1.10 Measurements of yield parameters of rice plants in 2016.**

| Treatment | Top air-dry weight per hill (g) | Yield (winnowed rough rice) per hill (dry weight, g) | Number of productive panicles per hill | Average Number of spikelets per panicle | Percentage of ripened grains (%) | 1000-winnowed rough rice (dry weight, g) | Culm length (cm) | Panicle length (cm) | Maximum tiller number per hill | Percentage of productive culms (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **$S_1$** | 81.7 b | 34.4 b | 22.0 cd | 83.0 ab | 87.5 a | 21.6 ab | 74.6 b | 18.3 a | 28.0 bc | 79.2 b |
| **$S_2$** | 110.7 c | 45.0 c | 25.7 de | 103.5 b | 79.4 a | 21.5 ab | 82.4 cd | 20.8 ab | 27.8 bc | 92.2 b |
| **$S_3$** | 119.3 c | 40.9 c | 28.3 e | 85.5 ab | 76.5 a | 22.3 bc | 81.5 c | 23.1 b | 32.5 c | 88.3 b |
| **$S_4$** | 117.3 c | 40.7 c | 23.5 de | 101.6 b | 74.2 a | 22.4 bc | 87.1 d | 23.2 b | 31.0 c | 76.6 b |
| **$F_1$** | 66.3 b | 23.7 a | 15.7 b | 85.5 ab | 81.6 a | 22.1 bc | 73.3 b | 18.3 a | 19.3 ab | 81.6 b |
| **$F_2$** | 76.1 b | 32.4 b | 17.7 bc | 90.9 ab | 86.5 a | 23.2 bc | 78.0 bc | 20.6 ab | 19.7 ab | 90.4 b |
| **$F_3$** | 86.2 b | 36.5 bc | 23.0 de | 82.9 ab | 82.0 a | 23.5 c | 77.3 bc | 21.1 b | 27.0 bc | 85.8 b |
| **$F_4$** | 73.1 b | 25.1 ab | 16.2 bc | 86.2 ab | 77.9 a | 23.8 c | 76.4 b | 21.7 b | 19.8 ab | 81.3 b |
| **CF** | 142.6 d | 44.8 c | 38.5 f | 81.2 ab | 72.4 a | 19.8 a | 86.3 cd | 19.7 a | 51.7 d | 75.0 b |
| **NF** | 25.5 a | 9.5 a | 7.3 a | 65.6 a | 88.0 a | 22.8 bc | 62.9 a | 17.6 a | 14.8 a | 49.6 a |

Means within each column with the same letter(s) are not significantly different at $P<0.05$.

**Weight of winnowed rough rice (Yield) (dry weight, g)**

The yield parameter which represented as the dry weight of weight of winnowed rough rice per hill of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer (CF) and no fertilizer (NF) treatments in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively.

In 2015, among different SSC treatments, weight of winnowed rough rice of treatment $S_4$ (57.6 g) depicted significantly higher than $S_1$ (29.2 g) and treatments NF and CF (6.4 and 38.4 g, respectively). However, treatments $S_2$ and $S_3$ (44.6 and 52.8 g, respectively) were found at par with treatment $S_4$. Within different FWC treatments, weight of winnowed rough rice of treatment $F_3$ (52 g) recorded significantly higher which it was at par with treatments $F_4$, $F_2$ and control treatment CF (41.1, 38.5 and 38.4 g, respectively). However, treatment $F_1$ recorded the significantly lower weight of winnowed rough rice (Table 1.9).

In 2016, among different SSC treatments, the weight of winnowed rough rice of treatments $S_2$, $S_3$, $S_4$, and control treatment CF did not significantly differ with each other but, treatment $S_1$ recorded the significantly lower. Within FWC treatments, weight of winnowed rough rice of treatment $F_3$ was found higher which was at par with control treatment CF however, treatment $F_1$ recorder lower weight of winnowed rough rice (Table 1.10).

**Number of productive panicle per hill**

Number of productive panicle of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), CF and no fertilizer (NF) treatments in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively.

Number of productive panicle was differ among different compost (SSC and FWC) and their levels. In 2015, within SSC treatments, the maximum number of productive panicle was registered in treatment $S_4$ (38.5), which was at par with treatments $S_2$, $S_3$ and CF (33.0, 32.3 and 39.5, respectively) however, the minimum was counted in treatment $S_1$ (24.0). Meanwhile, number of productive panicle of FWC treatments $F_1$, $F_2$, $F_3$ and $F_4$ did not significantly differ with each other (15.8, 21.3, 24.7 and 23.3, respectively) but, all FWC treatments were significantly smaller than control treatment CF (39.5) and higher than treatment NF (5.3) (Table 1.9).

In 2016, number of productive panicle of SSC treatments $S_2$, $S_3$, and $S_4$ were registered at par with each other, but higher than treatment $S_1$. The maximum productive panicle of FWC treatments was recorded in treatment $F_3$ (23.0) and followed by rest of FWC treatments. All SSC and FWC treatments were found lower than control treatment CF (38.5) and higher than treatments NF (7.3) (Table 1.10).

**Average number of spikelet per panicle**

Average number of spikelet per panicle of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively.

In 2015, the maximum average number of spikelet per panicle of SSC treatments was registered in treatment $S_4$ (100.5) which was at par with treatment $S_3$ (100.3), followed by treatments $S_2$ (76.6) and the minimum was counted in treatment $S_1$ (66.2). However, control treatment CF (84.6) was found at par with SSC treatments. The average number of spikelet per panicle of FWC treatments, recorded higher in treatment $F_3$ (117.9), which was at par with treatments $F_4$ and $F_2$ (107.4 and 100.4, respectively) and the lower was registered in treatment $F_1$ (85.7). Treatments $F_3$ and $F_4$ were recorded significantly higher average number of spikelet per panicle than control treatments CF and NF (84.6 and 60.8, respectively) (Table 1-9).

In 2016, average number of spikelet per panicle recorded no significant different among different of SSC and FWC treatments, both SSC and FWC treatments were at par with control treatment CF (Table 1.10).

**Percentage of ripened grains (%)**

Percentage of ripened grains of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), CF and no fertilizer (NF) treatments in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively. Percentage of ripened grains did not differ significantly among different composts (SSC and FWC) and their levels in 2015 and 2016.

In 2015, percentage of ripened grains of SSC and FWC treatments registered significantly higher than control treatment CF, except treatment F4 which was similar to CF. However, treatment NF recorded the highest percentage of ripened grains which was at par with treatments $S_1$, $S_2$, $S_3$, $F_1$ and $F_2$ (Table 1.9).

In 2016, no significant differ recorded between SSC, FWC, CF and NF treatments (Table 1.10).

**1000-winnowed rough rice (dry weight, g)**

1000-winnowed rough rice weight of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2015 and 2016 shown in Table 1.9 and Table 1.10, respectively.

In 2015, among SSC treatments, the significantly maximum 1000-winnowed rough rice weight was registered in treatment $S_1$ (22.6 g) which was at par with treatment NF (23.1 g) and the minimum was counted in treatment $S_4$ (20.5 g) which was at par with treatments $S_3$, $S_2$ and CF (21.1, 20.9 and 20.1 g, respectively). Among FWC treatments, the 1000-winnowed rough rice weight was recorded higher in treatment $F_4$ (23.8 g), at par with treatments $F_3$, $F_2$ and NF (23.5, 23.0 and 23.1 g, respectively) and the lower was registered in treatment $F_1$ (21.8 g). 1000-winnowed rough rice weight of control treatment CF was lower (20.1 g) than treatments $F_4$, $F_3$, $F_2$ and NF (Table 1.9).

In 2016, between SSC treatments, 1000-winnowed rough rice weight recorded no significant different. The 1000-winnowed rough rice weight also registered no significant different among FWC treatments. However, treatment CF was significantly lower than all SSC and FWC treatments except treatments $S_1$ and $S_2$ (Table 1.10).

**Culm length (cm)**

Culm length of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), CF and no fertilizer (NF) treatments in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively. Culm length was differed among different compost (SSC and FWC) and their levels in 2015 and 2016.

In 2015, among different SSC treatments, culm length of treatment $S_4$ (89.7 cm) depicted significantly higher, which was at par with treatment $S_3$ (86.3 cm) and the significantly lower was recorded in treatment $S_1$ (75.5 cm) which was at par with $S_2$ (80.1 cm). However, control treatment CF (86.0 cm) was at par with treatments $S_2$, $S_3$ and $S_4$ and significantly higher than treatments $S_1$. Within different FWC treatments, weight of culm length of treatment $F_4$ (84.6 cm) was recorded higher, it was at par with treatments $F_3$, $F_2$ and CF (82.1, 80.2 and 86 cm, respectively), however, treatment $F_1$ recorded the significantly lower culm length (74.9 cm) (Table 1.9).

In 2016, for SSC treatments, the significantly maximum culm length was found in treatment $S_4$ which was at par with control treatment CF and the significantly minimum was registered in treatment $S_1$. Culm length for FWC treatments, did not show significant different among different FWC treatments (Table 1.10).

**Panicle length (cm)**

Panicle length of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), CF and no fertilizer (NF) treatments in 2015 and 2016 are shown in Table 1.9 and Table 1.10, respectively.

In 2015, among different SSC treatments, panicle length of treatment $S_4$ (20.0 cm) was depicted higher but at par with treatments $S_1$, $S_2$ and $S_3$ (18.2, 18.4 and 19.7 cm, respectively) and control treatments NF and CF (17.5 and 19.3 cm, respectively). Within different FWC treatments, panicle length of treatment $F_3$ (23.1 cm) was recorded significantly higher than treatments $F_1$, $F_2$ and control treatments CF and NF (18.3, 20.2, 19.3 and 17.5 cm, respectively) (Table 1-9).

In 2016, for SSC treatments, the maximum panicle length was counted in treatment $S_4$ (23.2 cm) which was at par with treatment $S_3$ and $S_2$ (23.1 and 20.8 cm, respectively) however, the minimum was found in treatment $S_1$ (18.3 cm) which was at par with control treatment CF (19.7 cm). For FWC treatments, the maximum panicle length was found in treatment $F_4$ (21.7 cm) which was at par with treatments $F_3$ and $F_2$ (21.1 and 20.6 cm, respectively) however, the minimum was recorded in treatment $F_1$ (18.3 cm) which was at par with control treatment CF (19.7 cm) (Table 1.10).

**Percentage of productive culms (%)**

Percentage of productive culms of SSC ($S_1$, $S_2$, $S_3$ and $S_4$), FWC ($F_1$, $F_2$, $F_3$ and $F_4$), CF and no fertilizer (NF) treatments in 2015 and 2016 are shown in table 1.9 and table 1.10, respectively.

In 2015, among different levels of SSC treatments, treatment $S_3$ (86.1) recorded significantly higher percentage of productive culms than treatments $S_1$ and NF (64.5 and 61.7, respectively), treatments $S_4$ and $S_2$ (85.8 and 82.3, respectively) were at par with treatment $S_3$, and the significant minimum was counted in treatment $S_1$ (64.5). Within FWC treatments, percentage of productive culms was found maximum in treatment $F_3$ (97.2) which was at par with treatments $F_4$ and $F_2$ (94.3 and 93.3, respectively) and the minimum was recorded for treatment $F_1$ (68.8). Control treatment CF (69.9) was at par with treatments $F_1$, $F_2$ and $F_4$ but significantly lower than treatment $F_3$ (Table 1.9).

In 2016, percentage of productive culms did not significantly differ among different SSC, FWC and CF treatments. However, NF treatment registered the significant lowest percentage of productive culms than all SSC, FWC and CF treatments (Table 1.10).

Table 1.11 shows the three-way ANOVA table and multiple comparison of yield, using all treatments' data of two years. To determine the effects of compost application on yield of all treatments, data from two years were subjected to three-way ANOVA. Subsequently, Tukey multiple comparisons were performed on all treatments. No significant differences in yield were observed between the CF treatment and other treatments, except S1, F1, and NF (Table 1.11).

Table 1.12 shows the four-way ANOVA table and multiple comparison of yield, using the two years data of composts treatments. In order to analyze effects of quality (Types) and quantity (amount) of compost on yield, yield data of compost treatments from two years were subjected to four-way ANOVA. Subsequently, Tukey multiple comparisons were performed. Quality as compost type, quantity as amount of compost applied and year were significantly different by four-way ANOVA. SSC as compost type was powerful and significantly contributed to yield (43.2 g per pot) than FWC (34.0 g per pot). The yield was significantly increased with the amount of compost contained 11.0 g N per pot. The contribution of compost to yield was no significant difference between 11.0, 16.5 and 22.0 g N as amount of compost applied per pot (40.1, 45.5 and 41.1 g yield per pot, respectively), and the amount of compost with 5.5 g N per pot recorded the significantly low yield (27.5 g per pot) (Table 1.12) (Table 1.12).

**Table 1.11 Three-way ANOVA table and multiple comparison of yield, using all treatments data of two years.**

| Source of variation | df | SS | MS | F-stastic | P-value | |
|---|---|---|---|---|---|---|
| Treatments(T) | 9 | 8663.3 | 962.6 | 41.2 | 0.0000 | ** |
| Blocks (B) | 2 | 75.5 | 37.8 | 1.6 | 0.2263 | |
| Year(Y) | 1 | 381.3 | 381.3 | 16.3 | 0.0008 | ** |
| T x B | 18 | 660.8 | 36.7 | 1.6 | 0.1733 | |
| T x Y | 9 | 1176.4 | 130.7 | 5.6 | 0.0010 | ** |
| B x Y | 2 | 66.5 | 33.3 | 1.4 | 0.2668 | |
| Error | 18 | 420.6 | 23.4 | | | |
| Total | 59 | 11444.5 | | | | |

**Multiple comparison of yield**

| Treatment | yield (g per hill) | |
|---|---|---|
| **$S_1$** | 31.8 | b |
| **$S_2$** | 44.8 | d |
| **$S_3$** | 46.8 | d |
| **$S_4$** | 49.2 | d |
| **$F_1$** | 23.2 | b |
| **$F_2$** | 35.5 | c |
| **$F_3$** | 44.2 | d |
| **$F_4$** | 33.1 | bc |
| **CF** | 41.6 | cd |
| **NF** | 7.9 | a |

** Significant at 0.01 level of probability. * Significant at 0.05 level of probability. Means within each column with the different letter(s) are significantly different at $P<0.05$ by Tukey test.

**Table 1.12 Four-way ANOVA table and multiple comparison of yield, using the two years data of composts treatments.**

| Source of variation | df | SS | MS | F-stastic | P-value | |
|---|---|---|---|---|---|---|
| Types (T) | 1 | 999.8 | 999.8 | 90.0 | 0.0001 | ** |
| Blocks (B) | 2 | 45.0 | 22.5 | 2.0 | 0.2125 | |
| Amount (A) | 3 | 2155.1 | 718.4 | 64.7 | 0.0001 | ** |
| Year (Y) | 1 | 672.8 | 672.8 | 60.6 | 0.0002 | ** |
| T x B | 2 | 20.8 | 10.4 | 0.9 | 0.4422 | |
| T x A | 3 | 271.9 | 90.6 | 8.2 | 0.0154 | * |
| T x Y | 1 | 34.1 | 34.1 | 3.1 | 0.1301 | |
| B x A | 6 | 186.3 | 31.1 | 2.8 | 0.1182 | |
| B x Y | 2 | 80.3 | 40.2 | 3.6 | 0.0932 | |
| A x Y | 3 | 753.7 | 251.2 | 22.6 | 0.0011 | ** |
| T x B x A | 6 | 383.1 | 63.9 | 5.8 | 0.0257 | * |
| T x B x Y | 2 | 30.2 | 15.1 | 1.4 | 0.3256 | |
| T x A x Y | 3 | 21.9 | 7.3 | 0.7 | 0.6080 | |
| B x A x Y | 6 | 308.6 | 51.4 | 4.6 | 0.0421 | * |
| Error | 6 | 66.6 | 11.1 | | | |
| Total | 47 | 6030.2 | | | | |

**Multiple comparison**

| **Factor** | | **Mean** | |
|---|---|---|---|
| Types | SSC | 43.2 | b |
| | FWC | 34.0 | a |
| Blocks | B1 | 38.1 | |
| | B2 | 39.9 | |
| | B3 | 37.7 | |
| Amounts | 5.5 g T-N/pot | 27.5 | a |
| | 11.0 g T-N/pot | 40.1 | b |
| | 16.5 g T-N/pot | 45.5 | c |
| | 22.0 g T-N/pot | 41.1 | bc |
| Years | 2015 | 42.3 | b |
| | 2016 | 34.8 | a |

** Significant at 0.01 level of probability. * Significant at 0.05 level of probability.

Relationship between amount of total nitrogen (g/pot) and treatment name was as follows, 5.5 g (S1,F1), 11.0 g (S2,F2), 16.6 g (S3,F3) and 22.0 g (F4,S4).

## Discussion

The results of experiment have been presented in preceding topics. They are required to be discussed in the light of scientific knowledge and principles of Agronomy. Interpretations have been made in the view of the factors governing the manifestation of result and their corroboration light of results obtained by other scientist workers engaged in the relative field of research. The result of this study show significant effects of application of SSC and FWC with their levels on growth and yield of rice plant. The growth parameters and yield components were differed by different compost and their levels.

### Growth characters

CF treatment was popularly used for basal and top dressing. We compared eight treatments of compost, with varying type and amount of application, with CF and NF treatments. The early growth stage of rice plant was inhibited by application of SSC and FWC compared to chemical fertilizer (CF), the growth depression of rice plants caused by SSC and FWC relative to CF was observed in all the growth parameters examined, particularly in leaf emergence pattern (Table 1.3), plant length (Table 1.4) and tiller number (Table 1.5) in 2015 and 2016. Leaf emergence pattern, plant length and tiller number were decreased and inhibited by increasing level of compost at initial growth stag however, at the late growth stage they were conversely increased by increasing level of compost. The application of SSC was more effective on growth parameters and was performed better than FWC. Since this inhibition of these growth parameters was consistently observed for two years, and the composts used were middle mature, it might be related to characteristics of the compost used in this study. The depression phenomenon in growth has been also previously reported in pot experiments using SSC-like compost (Nagaya *et al.*, 2013) and in field experiments using farmyard manure (Maeda *et al*., 2005; Sakai and Yamamoto, 1999; Tamaki *et al*., 2002).

The lower levels of SSC and FWC treatments produced higher growth parameters at the early growth stage (1-6 WAT), but the growth parameters were smaller while at the late stage by application of lower levels of SSC and FWC. The higher growth parameters were produced by the higher levels of application. It was indicated that the early growth stage was inhibited temporal by SSC and FWC application and afterward most of the growth parameters at the late stage were increased. This phenomenon suggested the presence of inhibitor for a while after mixing compost with paddy soil. However, these inhibitory effects gradually decreased with time, and rice plants treated with various levels of SSC and FWC successfully reached maturity (Table 1.6). Similar result was report by Nishikawa *et al*., (2013) that the growth inhibition caused by anaerobically-digested manure (ADM) application was temporal, and most of growth parameters after the panicle initiation stage (approximately 45 DAT) were not inhibited. It might be related to positive effects of increasing nutrients availability by application of high levels of SSC and FWC at late growth stage. Ojobor *et al*., (2014) reported with a field experiment that increasing compost manure resulted to higher soil organic matter, total nitrogen, available phosphorus and available potassium. The tiller number of CF treatments found higher than SSC and FWC treatments, it might be due to the inhibition effects of SSC and FWC at the early growth stage (Table 1.5).

Time of harvesting of rice is important not only for its economics view, also for the quality of the grains. If the harvest date is delayed, the selling price will be affected. It was found that the duration from transplanting to heading stage and heading stage to maturity stage was longer by increasing level of SSC and FWC application. Maturity of rice plants was delayed by more than one week with $S_4$, $F_2$, $F_3$, and $F_4$ treatments compared with the CF treatment (Table 1.6). It might be due to inhibition effect of SSC and FWC application at the early growth stage, slowly released of nutrient from compost and availability of nutrient in the soil and up take by plant, the SPAD values in Table 1.8 can prove this statement. Higher levels of SSC and FWC recorded higher SPAD values at heading stage and 10 days after heading stage. For the purpose of early harvesting of rice plants using FWC and SSC application the early cultivation might be better. Early-season cultivation of rice plant was carried out in Mie prefecture by using main cultivar Koshihikari. (Mie 2015)

The soil pH values of SSC and FWC treatments at 8 WAT were closed to neutral and increased numerically by increasing levels of SSC and FWC. pH value of FWC was higher than SSC. While, the soil pH of treatment CF was recorded lower than SSC and FWC treatments (Table 1.7). It clarified that organic fertilizer could adjust soil acidity and improve soil pH. Olayinka and Adebayo (1985) also reported that compost manure has been found to be capable of improving soil pH because of the relative exchangeable Ca, Mg and K it contained.

The SPAD value, the most important one of plant growth characteristics, was highly correlated with leaf N and chlorophyll content of the paddy rice. SPAD values of top 3 leaves was differed by different compost (SSC and FWC) and their levels at heading stage and 10 days after heading stage. The SPAD value of top 3 leaves were increased by increasing level of SSC and FWC at heading stage and 10 days after heading stage, the SPAD value of high levels of SSC and FWC treatments ($S_4$, $S_3$, $F_4$ and $F_3$) were even higher than chemical fertilizer treatment (CF). It might be due to the higher nutrient availability (especially N) in the soil by levels of composts (SSC and FWC) application and had been increased plant uptake. Yoshida (1981) reported that rice leaf N content was influenced by amount and type of fertilizer. Myint *et al*., 2009 also reported that the SPAD value of flag leaf increase during the flowering period with different levels and kind of manure and fertilizer application. The SPAD values decreased at 10 days after heading stage especially in the lower leaves ($3^{rd}$ leaf). Similar findings have also been supported by Turner and Jund (1994), they found that the SPAD values of low N applied rice were increase at heading stage in a study using different rates of N application, and they explained that the lower leaf of the plant caused to senesce and translocate N to flag leaf, resulting in a greener flag leaf.

**Yield components**

Significant difference was observed on yield component with application of SSC and FWC and their levels in 2015 and 2016. The top air-dry weight increased by increasing level of SSC, higher level of SSC ($S_4$) produced significantly heavier top air-dry weight than CF. The top air-dry weight increased in FWC by increasing its level up to $F_3$. However, CF treatments produced heavier top air-dry weight than FWC treatments. The higher top air-dry weight of SSC and FWC might be due to more availability of nutrient in soil by decomposition of compost and uptake by plant during the vegetative growth stage, the SPAD value of leaves at heading stage (Table 1.8) can prove this statement. The lower top air-dry weight in FWC than CF might be due to the inhibition effect of growth parameters of FWC treatments at the early growth stage (Tables 1.3 to 1.5), at the early growth stage treatment $F_4$ inhibited stronger than treatment $F_3$, it might be the reason that treatment $F_3$ produced higher top air-dry weight than treatment $F_4$.

The main rice yield component indicators are number of productive panicle, average number of spikelet per panicle, percentage of ripened grains and weight of 1000-winnowed rough rice. From the result of this study it was found that application of low levels of SSC and FWC ($S_1$ and $F_1$) produced lower number of productive panicle and average number of spikelet per panicle but higher percentage of ripened grains and weight of 1000-winnowed rough rice, which resulting in lower yield in comparison to CF. However, application of high level of SSC and FWC ($S_4$ and $F_3$) produced lower number of productive panicle but higher average number of spikelet per panicle, percentage of ripened grains and weight of 1000-winnowed rough rice, which resulting in higher yield in comparison to CF. The reason for this result might be due to compost application supplied micro-elements such as Mg, S, and Zn in soil in addition to macro-elements. Therefore, the high levels of SSC and FWC treatments appeared to increase weight of winnowed rough rice compared with the chemical fertilizer treatments (CF). It was also reported by Nishikawa *et al*., (2012) that application of composts at higher N application than the standard application resulted in a higher N uptake and grain yield in a method which ADM was applied at basal dressing. The lower weight of winnowed rough rice of CF treatments was mainly related to the average number of spikelet per panicle, percentage of ripened grains, percentage of productive culms and weight of 1000-winnowed rough rice (Tables 1.9 and 1.10). FWC treatments displayed the lower value of yield components compared to SSC treatments, and it might be due to the negative effects which were taken at the early growth stage (Tables 1.3 to 1.5).

The 2-years yield data showed that the effects of compost application ($S_2$, $S_3$, $S_4$, $F_2$, $F_3$, and $F_4$ treatments) on yield was not significantly different than that of the CF application (Table 1.11). With respect to the compost type, the effect of SSC treatments on yield was significantly higher than that of FWC treatments. With respect to the compost quantity, the contribution of 5.5 g N level of the applied compost per pot on yield was significantly smaller than that of 11.0 g or more of N levels per pot (Table 1.12). To avoid soil pollution due to excessive nitrogen accumulation, $S_2$ and $F_2$ treatments (both at the rate of 11 g N per pot) were considered to be the most suitable instead of chemical fertilizer. Since the amount of nitrogen contained in the $S_2$ and $F_2$ treatments (11.0 g N per pot) was twice more than the amount of nitrogen in CF treatment (6.1 g N per pot), the nitrogen use efficiency of the SSC in the $S_2$ and $F_2$ treatments was estimated to be about half of chemical fertilizer (CF) treatment.

Before the Food Waste Recycling Law of Japan (2000) was enforced, most of the cyclical food resources, including food waste materials were incinerated and disposed in landfills. Converting such waste material into compost and using it as a supplement for food production helps preserve the environment (Inobushi and Ushikubo, 2015). SSC and FWC have been classified as ordinary and special fertilizers, respectively, under the Fertilizer Regulation Act. Ordinary fertilizer contains heavy metals, the level of which should be maintained below a certain level. Some animal manure composts contain heavy metal components at high concentrations (Orihara *et al*., 2002). SSC is thought to cause little environmental pollution, as it is controlled for the level of heavy metals and does not contain domestic animal excreta. FWC also causes minimal environmental pollution for the similar aforementioned reasons. Although, the level of heavy metals in these composts is considered to be below the reference value, they must be applied at an appropriate rate and amount to avoid environmental pollution.

The nitrogen concentration of SSC and FWC were relatively higher when compared with that in animal manure compost (Hioki *et al*., 2001). It is believed that less labor is involved in SSC and FWC application than in animal manure compost application due to less application amount is sufficient. For organic rice cultivation, 9.3 g N $m^{-2}$ of cattle manure (Asai *et al*., 2016) and 36 g N $m^{-2}$ of chicken manure (Arisawa, 2015) is used to supply the required N level for rice growth without increasing the N concentration in the brown rice. In this pot experiment, CF treatment as the conventional paddy cultivation was needed 6.1 g N per pot, whose equivalent yields was expected to be $S_2$ treatment containing 11.0 g N or $S_3$ and $F_3$ treatments containing 16.5 g N per pot (Table 1.9 and Table 1.10). Based on these data, it is possible to substitute compost corresponding to 1.8 – 2.7 the N level of the applied CF in the pot experiment. CF application at a rate of 7 g N $m^{-2}$ is needed for paddy cultivation in Mie prefecture (Mie, 2015). Then, the corresponding amount of compost (SSC or FWC) required for paddy cultivation was estimated to be approximately 12.6 – 18.9 g N $m^{-2}$. These application rates are considered to be within the acceptable range that the quality of brown rice does not deteriorate even if compost is applied.

Until now, farmers have mostly used homemade compost because of raw material procurement costs. However, since the waste treatment company got the raw material and treatment cost for income, the selling price of SSC and FWC is lower than the cost of preparing homemade compost (Nagaya, 2007). The waste treatment used to prepare SSC and FWC is inexpensive. Because SSC and FWC have a high N content, low price, and low heavy metal concentration, these composts were popular among local organic farmers in the area near the waste treatment company. Although farmers used SSC and FWC mostly for upland farming, from the result of this experiment we can suggest that these composts can also be used for paddy cultivation of lowland.

## Conclusion

The following conclusions have been drawn from 2 years results of present investigation. The basal application of organic composts (SSC and FWC) which produced from cyclical food resources were found effective on growth and yield components of rice plant. The early growth stage of rice plant was depressed by application of both composts and the depression was increased by increasing the amount of each compost, while the depression was reduced at the late stage. Regarding the yield components, there were significant differences among different composts (SSC and FWC) and their levels, the high level of SSC and FWC treatments ($S_4$ and $F_3$) was found to be effective and gave significantly higher productivity. Considering to the number of tiller at the early stage, date of maturity stage and productivity, the SSC performed better than FWC. The yield of SSC and FWC in the range of application amount which contained 11.0 g N per pot was found equivalent with 16.5 and 22.0 g N per pot, it was also at par with the yield of standard level of chemical fertilizer (6.1 g N per pot), therefore SSC and FWC basal application at the rate of 11.0 g N per pot was found safety and it can be recommended to be an alternative to chemical fertilizer (6.1 g N per pot).

Even though, the inhibitory effects of SSC and FWC application are still not fully understood, it is important to investigate more about inhibition effects and improve growth and yield of rice plant greater.

* * *

# Chapter Three

## Effects of different compost and different time of cultivation on the early growth stage of rice (*Oryza sativa* L.)

Compost made from organic wastes is one of good materials for crop production. The compost and manure mainly used by farmers in Japan were produced from crop residues and animal excreta. After the Food Waste Recycling Law of Japan (2000) was enforced, compost production from cyclical food resources, such as food waste, food processing residues and sewage sludge from food factories, wood chips, and grass clippings was increased. These new kinds of compost were not prepared directly from animal excreta (Nagaya, 2007). Sewage sludge compost (SSC) and food waste compost (FWC) which include and exclude sludge, respectively were used in this study.

Approximately one-third of the edible part of food produced for human consumption gets lost or wasted globally, which is about 1.3 billion ton per year (FAO, 2011). Food waste in Japan estimated 6.42 million ton per year (METI, 2016). Per capita food waste in developed countries and developing countries are 107 and 56 kg per year, respectively (Thi, *et al*., 2014). The composting of these food wastes to fertilize paddy field are beneficial from the perspective of a recycling economy and eco-friendly crop production. SSC and FWC are thought to cause little environmental pollution, as they controlled for the level of heavy metals and do not contain domestic animal excreta.

In our previous paper, we applied FWC and SSC on rice plants as basal dressing and it has been explained that slower leaf emergence, fewer tiller numbers, short plant length, and delayed heading were caused by SSC and FWC application and the growth inhibition increased by increasing the amount of composts at the early growth stage while it was decreased at the late stage. The depression in growth has been reported in pot experiments using SSC-like compost by Nagaya *et al*., (2013). Nishikawa *et al*., (2013) also reported in his field experiment that application of anaerobically-digested manure has temporal inhibition effect on growth parameters of rice plants, from transplanting to the active tillering stage compared to chemical fertilizer.

Time of transplanting of rice seedlings is thought to be effective to reduce the inhibition effects of compost. We believe that basal application of SSC and FWC with early transplanting might affect the root growth and development and it may mutually interact with the top of rice plants. The rice plants which are sensitive after transplanting can not grow properly with early transplanting however, late transplanting might be beneficial for SSC and FWC basal application. The objectives of this study were (i) to investigate the effects of SSC and FWC basal application on dry matter production, (ii) to confirm the early growth inhibition of rice plant due to compost (SSC and FWC) application, and (iii) to know the effects of different time of transplanting on the early growth stage of rice plant when food- and sludge-derived compost applied. Therefore, it was planned to investigate and elucidate the effects of compost mainly made from food waste (excepting livestock) on rice plant at the early growth stage, at different time of cultivation in the same year.

## Materials and Methods

The present investigation entitled "Effects of different compost applications and different time of cultivation on the early growth stage of rice (*Oryza sativa* L.)" was conducted in five seasonal repetitions during 2015-2016 for two years. The details about the climatic under which the present investigation was carried out, experimental material used, techniques employed and criteria for evaluation of treatments during the course of investigation have been described as below.

Site description and composting process were the same as first experiment which have been explained in chapter second (refer to pages 8-10).

**Treatments and experimental design**

The pot experiments were arranged in randomized block design (RBD) with 3 replications and repeated five times (3 repetitions in 2015 and 2 repetitions in 2016) under open field condition. Repetition of the experiment is act of cultivation and transplanting of rice plants in different dates in the same year. Three different times of transplanting in 2015 and two times of transplanting in 2016, hereafter each time of transplanting referred to as "repetition". We used 24 liter (L) containers with dimension of 46.4 cm (length) × 23.4 cm (width) × 22 cm (height) as pot in our experiments. Treatments included two types of compost (SSC and FWC), each at four total nitrogen (N) levels (5.5, 11.0, 16.5 and 22.0 g N $pot^{-1}$), chemical fertilizer (CF) at standard level (6.1 g N $pot^{-1}$) as control treatment and no fertilizer (NF) was used to know the degree of soil fertility. Cultivated three times in 2015 and two times in 2016. The 10 treatments' names were abbreviated as $S_1$, $S_2$, $S_3$ and $S_4$ for SSC; $F_1$, $F_2$, $F_3$, and $F_4$ for FWC, CF for standard level of chemical fertilizer treatment and NF for no fertilizer treatment. The N content per pot of $S_1$ and $F_1$ was 5.5 g; $S_2$ and $F_2$ was 11 g; $S_3$ and $F_3$ was 16.5 g; $S_4$ and $F_4$ was 22 g; CF was 6.1 g and NF was 0 g (Table 1.2 page 12). The amount of compost for each SSC and FWC treatments was determined based on the N level of each treatment.

Soil and pots preparation, application of compost and chemical fertilizer, variety used, spacing, irrigation management and inter-culture were the same as first experiment which have been explained in chapter second (refer to pages 13-15).

**Sowing and seed rate**

The seeds of rice (*Oryza sativa* L.) cultivar "Koshihikari" were soaked in water for 3 days at 30 °C temperature. Pregerminated seeds at the rate of 150 g was sown in the nursery boxes (58cm × 28cm × 3cm) which were filled with sterilized soil. The sowing dates of first, second and third repetitions in 2015 were on April 1$^{st}$, April 22$^{nd}$ and May 13$^{th}$, respectively and the sowing dates of first and second repetitions in 2016 were April 1$^{st}$ and April 22$^{nd}$, respectively (Table 2.1). The nursery boxes were located in the greenhouse under controlled temperature condition until four-leaf stage.

**Transplanting**

Seedlings were separated based on their leaf age and the seedlings at four-leaf stage were selected and transplanted into the pots. The transplanting dates of first, second and third repetitions in 2015 were on April 29$^{th}$, May 13$^{th}$ and June 3$^{rd}$, respectively and the transplanting dates of first and second repetition in 2016 were April 29$^{th}$ and May 13$^{th}$, respectively (Table 2.1).

**Sampling**

The plants of two inner hills in each pot were sampled separately, soil and roots of each sample were separated using water pressure. The whole plant of each hill was divided into three parts (leaf blade, leaf sheath and root), for determination of their dry matter production. The sampling dates of first, second and third repetitions in 2015 were on June 17$^{th}$, July 1$^{st}$ and July 22$^{nd}$, respectively and the sampling dates of first and second repetitions in 2016 were June 23$^{rd}$ and July 7$^{th}$, respectively, corresponded to be maximum tiller number stage. Table 2.1 indicates the sowing, transplanting and sampling dates, and accumulated daily temperature for 49 days from transplanting of three repetitions in 2015 and two repetitions in 2016.

The process for spacing, irrigation management, inter-culture, sampling and harvesting were the same as explained in chapter second (refer to page 12-13).

**Table 2.1 Days of sowing, transplanting and sampling.**

| Year | Repetitions | Sowing | Transplanting | Sampling | ADT** (°C days) |
|---|---|---|---|---|---|
| 2015 | First repetition* | 01-April | 29-April | 17-June | 1025.8 |
| | Second repetition | 22-April | 13-May | 01-July | 1066.3 |
| | Third repetition | 13-May | 03-June | 22-July | 1137.3 |
| 2016 | First repetition* | 01-April | 29-April | 23-June | 1007.1 |
| | Second repetition | 22-April | 13-May | 07-July | 1084.0 |

* Popular transplanting date in Mie prefecture, Japan. ** Accumulated Daily Temperature for 49 days from transplanting.

**Observations recorded**

In order to secure the effect of different treatments, the plant growth parameters (leaf emergence pattern, plant length, tiller numbers and soil pH) and dry matter productions of leaf blade, leaf sheath and root were recorded during the course of current pot experimentation.

**Plant growth parameters**

Leaf emergence pattern, plant length and tiller numbers were recorded every week starting at 14 days after transplanting in 2015 and at 13 days after transplanting in 2016. The growth data were collected from the two inner hills in each pot. The side hills' plants in each pot were used as border plants. The data of leaf emergence pattern, plant length (cm) and tiller number were recorded until the date of sampling of each repetition.

**Soil pH**

Soil pH was determined every week for 6 weeks by digital pH meter (PRN-41, FUJIWARA), starting one WAT at each repetition in 2015 and two WAT in 2016. The soil pH from 5-10 cm depth of two points in each pot was determined. The pH of two points was averaged to get per pot pH value.

**Dry matter production measurements**

Dry weight of samples of each hill were determined separately after sampling of each repetition in 2015 and 2016, the whole plants of each hill (sample) was divided into three parts (leaf blade, leaf sheath and root) and the dry weight of each part was determined in gram after drying for 3 days at 80 °C in a ventilated oven. Dry weight of the plants of two hills of the same pot was averaged to get the dry weight of leaf blade, leaf sheath and root per hill.

### Top-Root ratio (T-R ratio)

The T-R ratio is simply the ratio of the top/aboveground biomass (leaf sheath and leaf blade) of the plant (T), to the roots of the plants (R). T-R ratio was calculated with the help of following formula:

$$\text{T - R ratio} = \frac{\text{Leaf sheath} + \text{Leaf plades}}{\text{Roots}}$$

### Statistical analysis

The data obtained from different observations were analyzed by the same way explained in first experiment (refer to chapter second, pages 19).

## Results

### Crop weather relationship

The performance of the rice plant is highly influenced by prevailing weather conditions, therefore data of rainfall and temperature collected during the crop seasons. The 10 days average temperature (°C) and the amount of rainfall (mm) during the experiments from April 1st to the end of July 2015 and 2016 in Tsu city, Mie Prefecture shown in Fig. 2.1. In comparison to 30 years (1981-2010) data of temperature and rainfall it was assumed that the weather conditions during the experimental period was normal in both years.

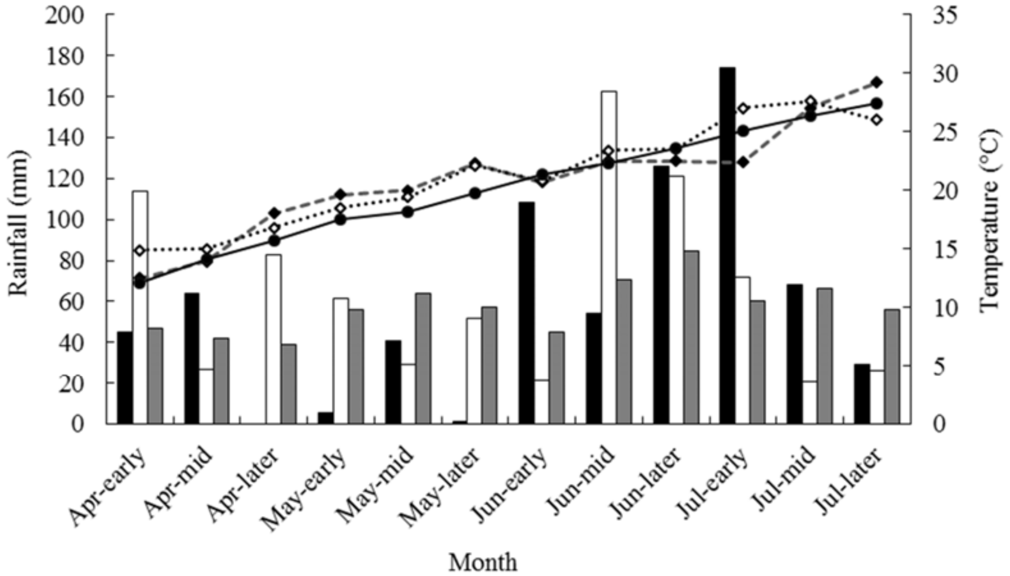



**Fig. 2.1 Measurements of temperature and rainfall during April-July in 2015 and 2016.**

**1. Effects on plant growth characters:**

The results of this study show obviously effects of application of SSC and FWC with their levels on plant growth parameters of rice. Leaf emergence pattern, plant length and tiller number were differed by different compost and their levels at early growth stage of rice in different repetitions of 2015 and 2016.

**Leaf emergence pattern (leaf age)**

The means of leaf emergence pattern of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of three repetitions in 2015 and two repetitions in 2016 are shown in Fig. 2.2 and Table 2.2.

In first repetition of 2015 (transplanted on 29 April), the leaf emergence pattern of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their levels until 5 WAT (a1 in Fig. 2.2). Leaf emergence pattern did not significantly differ at 7 WAT, but numerically the high leaf emergence pattern was found in treatments $S_1$ and $S_2$ (11.1 and 11.1, respectively) and the minimum was shown in treatments $S_3$ and $S_4$ (10.9 and 10.9, respectively), control treatment CF was registered at par with all SSC treatments. Treatment $S_4$ was depressed in comparison to control treatment NF until 5 WAT (a1 in Fig. 2.2). In second repetition of 2015 (transplanted on 13 May), the leaf emergence pattern of SSC treatments did not significantly differ throughout the initial plant growth, leaf emergence pattern of SSC treatments were not depressed in comparison to control treatment NF (a3 in Fig. 2.2). In third repetition of 2015 (transplanted on 3 June), SSC treatments indicated the same tendency as second repetition of 2015 and were no depressed in comparison to control treatment NF (a5 in Fig. 2.2).

In first repetition of 2016 (transplanted on 29 April), the leaf emergence pattern decreased by increasing level of SSC until 5 WAT. At 7 WAT the high leaf emergence pattern was found in treatments $S_1$ (11.4) and the minimum was recorded in treatment $S_4$ (10.7), control treatment CF was registered at par with treatment $S_1$ and higher than rest of treatments. Treatment $S_4$ was depressed in comparison to control treatment NF (a7 in Fig. 2.2). In second repetition of 2016 (transplanted on 13 May), leaf emergence pattern of SSC treatments were not depressed in comparison to control treatment NF (a9 in Fig. 2.2).

In first repetition of 2015 (transplanted on 29 April), the leaf emergence pattern of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) was significantly inhibited by increasing their levels throughout the plant life, at 7 WAT the high leaf emergence pattern was found in treatment $F_1$ (10.4), and the significant minimum was found in treatments $F_4$ (8.7) which was at pat with treatments $F_2$ and $F_3$ (9.6 and 9.5, respectively). Control treatment CF recorded significantly higher (11.7) than all FWC treatments, treatment $F_4$ was even significantly smaller than control treatment NF (paddy soil condition with no fertilizer) (a2 in Fig. 2.2). In second repetition of 2015 (transplanted on 13 May), the leaf emergence pattern was also decreased by increasing levels of FWC, at 7 WAT the high leaf emergence pattern was found in treatment $F_1$ (10.4), which was at par with treatments $F_2$ and $F_3$ (10.0 and 9.8, respectively) and the significant minimum was found in treatments $F_4$ (9.2). Control treatments CF recorded significantly higher (11.9) than all FWC treatments and treatment NF was found at par with $F_1$ and higher than rest of FWC treatments (a4 in Fig. 2.2). In third repetition of 2015 (transplanted on 13 May), FWC treatments indicated the same tendency as second repetitions of 2015 (a6 in Fig. 2.2).

In first repetition of 2016 (transplanted on 29 April), the leaf emergence pattern of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) was significantly inhibited by increasing their levels throughout the plant life, at 7 WAT the high leaf emergence pattern was found in treatment $F_1$ (10.5) which was at pat with treatment $F_2$ (10), and the significant minimum was found in treatments $F_4$ (8.9) which was at pat with treatment $F_3$ (9.3). Control treatment CF recorded significantly higher (11.9) than all FWC treatments, treatment $F_4$ was even significantly smaller than treatment NF (paddy soil condition with no fertilizer) (a8 in Fig. 2.2). In second repetition of 2016 (transplanted on 13 May), the leaf emergence pattern was also decreased by increasing levels of FWC, at 7 WAT the high leaf emergence pattern was found in treatment $F_1$ (11.4), which was at par with treatment $F_2$ (11.2) and the significant minimum was found in treatments $F_4$ (10.8) which was at par with treatment $F_3$ (11). Control treatment CF recorded significantly higher (12.5) than all FWC treatments (a10 in Fig. 2.2).

From the results of three repetitions in 2015 and two repetitions in 2016 (Table 2.2 and Fig. 2.2), it was found that there was no different of leaf emergence pattern between second and third repetitions but first repetition in 2015 and 2016 were inhibited heavier than second and third repetitions. The leaf emergence pattern depression caused by FWC was more than SSC in all repetitions of 2015 and 2016 and the depression was increased by increasing levels of the composts, treatments $S_4$ and $F_4$ (high levels of compost) were most depressed in comparison to control treatment CF and they were even smaller than treatment NF (paddy soil condition with no fertilizer). Control treatment CF recorded higher leaf emergence pattern than all SSC and FWC treatments.

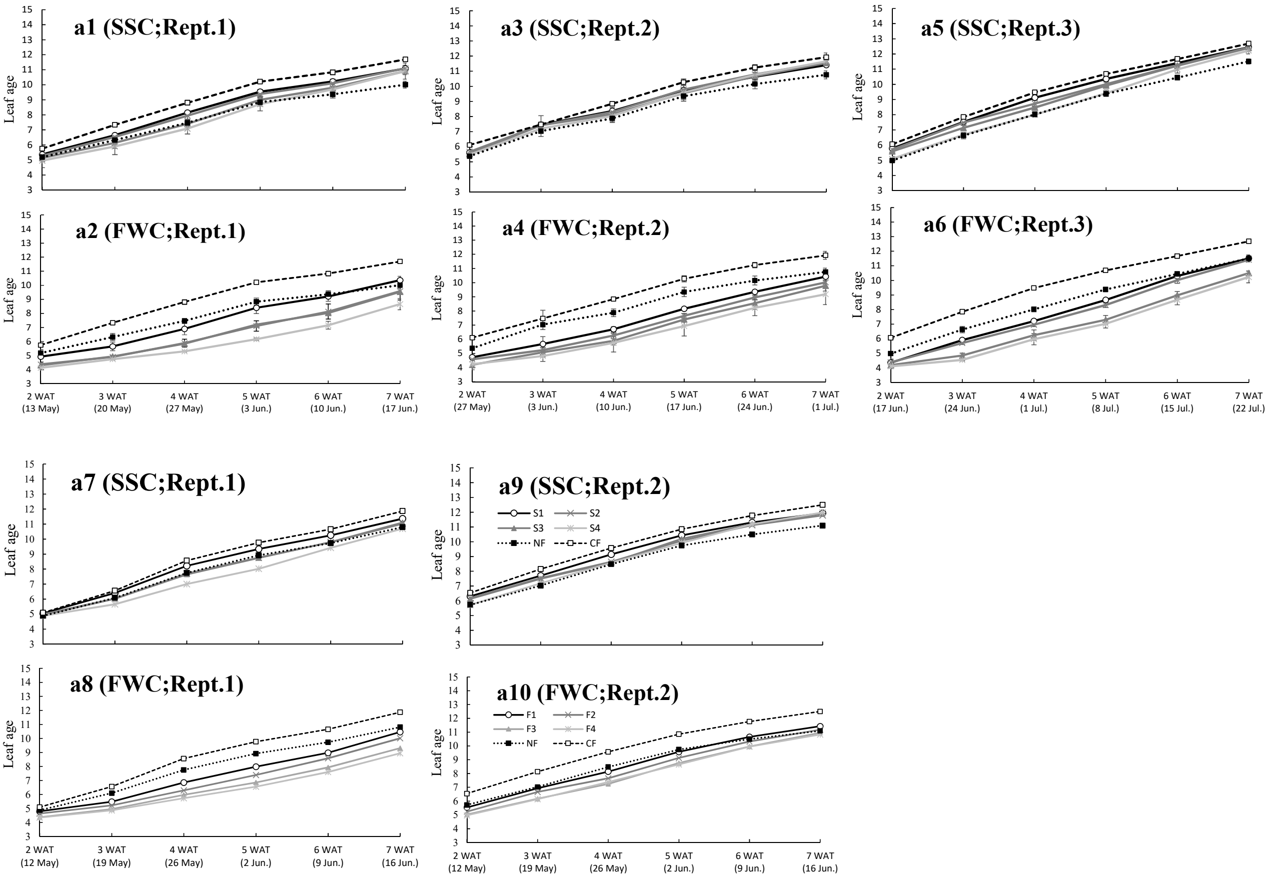



**Fig. 2.2 Effects of SSC and FWC application on leaf age (leaf emergence pattern) at the early stage of rice plant in 2015 and 2016.**

a1-a6 show leaf emergence pattern (leaf age) in 2015. a7-a10 show leaf emergence pattern (leaf age) in 2016. First repetition of 2015 indicated in a1 and a2, second repetition in a3 and a4 and third repetition in a5 and a6. First repetition of 2016 indicated in a7 and a8 and second repetition in a9 and a10. Data represent mean ± standard deviation (n = 3). Rept. means repetition. WAT: week after transplanting.

**Table 2.2 Leaf age (Leaf emergence pattern) in 2015 and 2016.**

| Years | | First repetition | | | | | | Second repetition | | | | | | Third repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul |
| 2015 | **S1** | 5.4 | 6.6 | 8.2 | 9.5 | 10.2 | 11.1 de | 5.6 | 7.5 | 8.4 | 9.7 | 10.6 | 11.4 de | 5.8 | 7.5 | 9.1 | 10.4 | 11.4 | 12.5 c |
| | **S2** | 5.3 | 6.5 | 7.9 | 9.4 | 10.1 | 11.1 de | 5.7 | 7.4 | 8.3 | 9.8 | 10.8 | 11.6 de | 5.7 | 7.5 | 8.7 | 10.0 | 11.3 | 12.4 c |
| | **S3** | 5.1 | 6.1 | 7.4 | 9.0 | 9.8 | 10.9 cde | 5.5 | 7.4 | 8.1 | 9.6 | 10.7 | 11.5 de | 5.6 | 7.1 | 8.5 | 9.9 | 11.2 | 12.4 c |
| | **S4** | 5.0 | 5.9 | 7.1 | 8.7 | 9.7 | 10.9 cde | 5.5 | 7.2 | 8.0 | 9.6 | 10.8 | 11.7 e | 5.1 | 6.7 | 8.0 | 9.4 | 11.0 | 12.2 c |
| | **F1** | 4.9 | 5.7 | 6.9 | 8.4 | 9.2 | 10.4 bd | 4.7 | 5.7 | 6.7 | 8.2 | 9.4 | 10.4 bc | 4.4 | 5.9 | 7.2 | 8.7 | 10.3 | 11.5 b |
| | **F2** | 4.4 | 4.9 | 5.9 | 7.1 | 8.1 | 9.6 ab | 4.6 | 5.2 | 6.3 | 7.7 | 9.0 | 10.0 ac | 4.4 | 5.7 | 7.0 | 8.3 | 10.0 | 11.4 b |
| | **F3** | 4.3 | 4.9 | 5.9 | 7.2 | 8.0 | 9.5 ab | 4.2 | 5.1 | 5.9 | 7.4 | 8.5 | 9.8 ab | 4.2 | 4.8 | 6.2 | 7.3 | 9.0 | 10.5 a |
| | **F4** | 4.1 | 4.7 | 5.3 | 6.2 | 7.2 | 8.7 a | 4.2 | 4.8 | 5.8 | 6.9 | 8.2 | 9.2 a | 4.1 | 4.5 | 6.0 | 7.0 | 8.7 | 10.2 a |
| | **NF** | 5.2 | 6.3 | 7.5 | 8.8 | 9.4 | 10.0 bc | 5.4 | 7.0 | 7.9 | 9.3 | 10.2 | 10.8 cd | 5.0 | 6.6 | 8.0 | 9.4 | 10.4 | 11.5 b |
| | **CF** | 5.8 | 7.3 | 8.8 | 10.2 | 10.8 | 11.7 e | 6.1 | 7.5 | 8.8 | 10.3 | 11.2 | 11.9 e | 6.1 | 7.9 | 9.5 | 10.7 | 11.7 | 12.7 c |
| | Treatment | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun | | | | | | |
| 2016 | **S1** | 5.1 | 6.4 | 8.2 | 9.3 | 10.3 | 11.4 ef | 6.3 | 7.7 | 9.1 | 10.4 | 11.3 | 11.9 e | | | | | | |
| | **S2** | 5.0 | 6.0 | 7.7 | 8.8 | 9.8 | 11.0 de | 6.2 | 7.5 | 8.6 | 10.1 | 11.1 | 11.8 d | | | | | | |
| | **S3** | 4.9 | 6.0 | 7.7 | 8.7 | 9.8 | 11.1 de | 6.1 | 7.5 | 8.6 | 10.2 | 11.2 | 11.9 cd | | | | | | |
| | **S4** | 4.9 | 5.7 | 7.0 | 8.0 | 9.4 | 10.7 cd | 5.7 | 7.2 | 8.6 | 9.9 | 11.2 | 12.0 bd | | | | | | |
| | **F1** | 4.8 | 5.5 | 6.9 | 8.0 | 9.0 | 10.5 bc | 5.5 | 6.9 | 8.1 | 9.6 | 10.7 | 11.4 bc | | | | | | |
| | **F2** | 4.6 | 5.2 | 6.3 | 7.4 | 8.6 | 10.0 b | 5.2 | 6.7 | 7.7 | 9.1 | 10.3 | 11.2 ab | | | | | | |
| | **F3** | 4.4 | 5.0 | 6.0 | 6.9 | 7.9 | 9.3 a | 5.0 | 6.2 | 7.2 | 8.8 | 10.0 | 11.0 a | | | | | | |
| | **F4** | 4.4 | 4.9 | 5.7 | 6.6 | 7.6 | 8.9 a | 5.0 | 6.1 | 7.4 | 8.7 | 9.9 | 10.8 a | | | | | | |
| | **NF** | 4.9 | 6.1 | 7.8 | 8.9 | 9.7 | 10.8 cd | 5.7 | 7.0 | 8.5 | 9.7 | 10.5 | 11.1 cd | | | | | | |
| | **CF** | 5.1 | 6.6 | 8.6 | 9.8 | 10.7 | 11.9 fg | 6.5 | 8.1 | 9.6 | 10.9 | 11.8 | 12.5 f | | | | | | |

**Plant length (cm)**

The means of plant length (cm) of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of three repetitions in 2015 and two repetitions of 2016 are shown in Table 2.3 and Fig. 2.3.

In first repetition of 2015 (transplanted on 29 April), the plant length of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their level during the plant growth, At 7 WAT the high plant length was found in treatments $S_1$ (62.5 cm), followed by treatments $S_2$ and $S_3$ (60.3 and 57.7 cm, respectively) and the minimum was shown in treatment $S_4$ (49.8 cm), control treatment CF recorded higher (67.7 cm) than all SSC treatments and treatment $S_4$ was most depressed in comparison to control treatment CF (b1 in Fig. 2.3). In second repetition of 2015 (transplanted on 13 May), the levels of SSC treatments did not significantly differ. However, control treatment CF recorded significantly higher (78.5 cm) and treatment NF registered significantly lower (48.5 cm) plant length than all SSC treatments (b3 in Fig. 2.3). In third repetition of 2015 (transplanted on 3 June), plant length of SSC treatments indicated the same tendency as second repetitions of 2015. Control treatment NF registered significantly lower (48.5 cm) plant length than all SSC treatments but treatment CF was at pat with them (b5 in Fig. 2.3).

In first repetition of 2016 (transplanted on 29 April), the plant length of SSC treatments decreased by increasing their level during the initial plant growth. At 7 WAT the high plant length was found in treatments $S_1$ (60.3 cm), followed by treatments $S_2$ and $S_3$ (54.3 and 55 cm, respectively) and the minimum was shown in treatment $S_4$ (53 cm), control treatment CF recorded higher (71 cm) than all SSC treatments and treatment $S_4$ was most depressed in comparison to control treatment CF, until 6 WAT treatments $S_4$ and $S_3$ were lower than treatment NF (b7 in Fig. 2.3). In second repetition of 2016 (transplanted on 13 May), the levels of SSC treatments did not significantly differ. However, control treatment CF recorded significantly higher (86.5 cm) than treatment $S_4$ (73.2 cm) and at par with rest of SSC treatments. Treatment NF registered significantly lower (57 cm) plant length than all SSC treatments (b9 in Fig. 2.3).

In first repetition of 2015 (transplanted on 29 April) plant length of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) was significantly decreased by increasing their levels during the plant growth, at 7 WAT, the high plant length was found in treatment $F_1$ (48.8 cm), followed by treatments $F_3$ and $F_2$ (39.0 and 36.0 cm, respectively) and the significant minimum was found in treatments $F_4$ (29.3 cm). Control treatment CF recorded significantly higher (67.7 cm) than all FWC treatments, treatments $F_4$, $F_3$ and $F_2$ were most depressed in comparison to control treatment CF and they were even significantly smaller than treatment NF (paddy soil condition with no fertilizer) until 6 WAT (b2 in Fig. 2.3). In second repetition of 2015 (transplanted on 13 May), the plant length was decreased by increasing levels of FWC, the high plant length was found in treatment $F_1$ (45.7 cm), followed by treatments $F_2$ and $F_3$ (41 and 37.7 cm, respectively) and the significantly minimum was found in treatments $F_4$ (35.2 cm). Control treatments CF recorded highest (78.5 cm) than all FWC treatments, treatment NF registered significantly higher plant length (48.5 cm) than treatment $S_4$ but at par with rest of FWC treatments (b4 in Fig. 2.3). In third repetition of 2015 (transplanted on 3 June), plant length of FWC treatments indicated the same tendency as second repetitions of 2015 (b6 in Fig. 2.3).

In first repetition of 2016 (transplanted on 29 April) plant length of FWC treatments was significantly decreased by increasing their levels during the plant growth, at 7 WAT the high plant length was found in treatment $F_1$ (48.3 cm), followed by treatments $F_3$ and $F_2$ (44.7 and 39.0 cm, respectively) and the significant minimum was found in treatments $F_4$ (32.7 cm). Control treatment CF recorded significantly higher (71.1 cm) than all FWC treatments. Treatments $F_4$, $F_3$ and $F_2$ were most depressed in comparison to control treatment CF and they were even significantly smaller than treatment NF (paddy soil condition with no fertilizer) until 6 WAT (b8 in Fig. 2.3). In second repetition of 2016 (transplanted on 13 May), the plant length was decreased by FWC application but there was no significant different between FWC treatments and control treatment NF. However, control treatment CF recorded significantly higher plant length than all FWC treatments (b10 in Fig. 2.3).

From the results of three repetitions in 2015 and two repetitions in 2016, it was found that there was no different of plant length between second and third repetitions however, first repetition in 2015 and 2016 were inhibited heavier than second and third repetitions. The plant length depression caused by FWC was more than SSC in all repetitions of 2015 and 2016, and the depression was increased by increasing levels of the composts, treatments $S_4$ and $F_4$ (high level of compost) were most depressed in comparison to control treatment CF and they were even smaller than NF (paddy soil condition with no fertilizer). Control treatment CF recorded higher plant length than all SSC and FWC treatments.

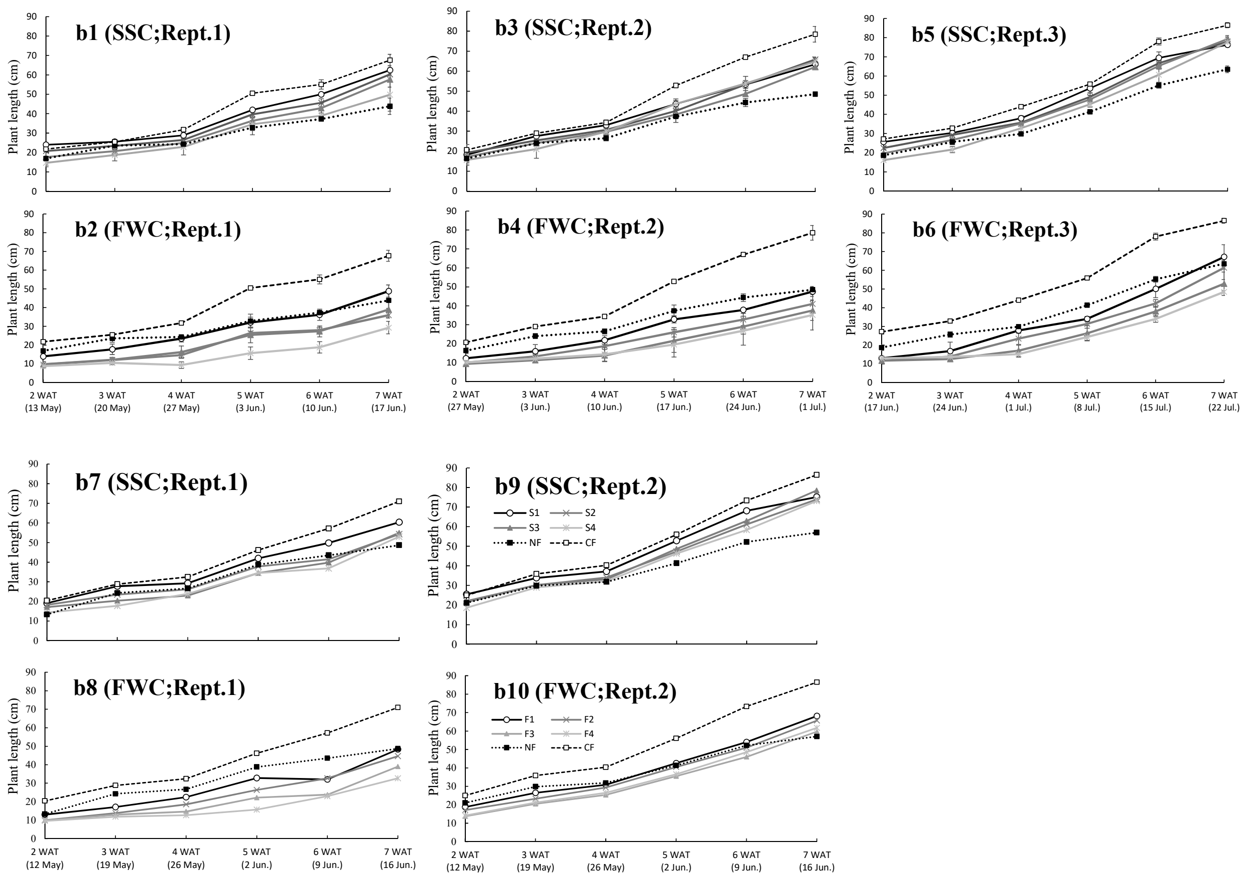



**Fig. 2.3 Effects of SSC and FWC application on plant length at the early stage of rice plant in 2015 and 2016.**

b1-b6 show plant length in 2015. b7-b10 show plant length in 2016. First repetition of 2015 indicated in b1 and b2, second repetition in b3 and b4 and third repetition in b5 and b6. First repetition of 2016 indicated in b7 and b8 and second repetition in b9 and b10.

Data represent mean ± standard deviation (n = 3). Rept. means repetition. WAT: week after transplanting.

Table 2.3 Plant length (cm) in 2015 and 2016.

| Years | | First repetition | | | | | | Second repetition | | | | | | Third repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul |
| 2015 | S1 | 24.0 | 25.6 | 28.9 | 42.0 | 50.0 | 62.5 e | 18.2 | 27.6 | 33.0 | 43.7 | 53.3 | 63.5 c | 25.7 | 30.3 | 38.0 | 53.7 | 69.5 | 76.3 de |
| | S2 | 20.8 | 23.4 | 26.5 | 39.7 | 45.7 | 60.3 de | 19.2 | 25.4 | 30.7 | 40.2 | 53.3 | 65.8 cd | 22.5 | 29.3 | 35.7 | 49.2 | 66.7 | 78.0 e |
| | S3 | 17.7 | 20.8 | 25.0 | 36.3 | 42.9 | 57.7 de | 17.1 | 24.0 | 29.7 | 38.3 | 48.7 | 62.2 c | 19.7 | 26.7 | 35.2 | 47.8 | 65.3 | 79.3 e |
| | S4 | 14.7 | 18.8 | 22.9 | 34.6 | 39.0 | 49.8 cd | 15.7 | 21.1 | 29.8 | 43.7 | 53.8 | 64.8 cd | 16.2 | 21.7 | 32.8 | 45.3 | 60.7 | 77.7 de |
| | F1 | 13.9 | 17.8 | 23.5 | 32.1 | 36.2 | 48.8 cd | 12.3 | 16.0 | 21.8 | 32.8 | 37.8 | 47.5 b | 13.0 | 16.8 | 27.8 | 34.0 | 50.0 | 67.2 cd |
| | F2 | 9.7 | 12.0 | 14.7 | 26.4 | 27.9 | 36.0 ab | 10.0 | 13.3 | 18.7 | 26.0 | 32.7 | 41.0 ab | 11.7 | 13.9 | 23.5 | 31.3 | 42.3 | 61.3 bc |
| | F3 | 9.8 | 12.2 | 16.3 | 25.4 | 27.3 | 39.0 ac | 9.3 | 11.3 | 13.8 | 21.5 | 29.0 | 37.5 ab | 11.7 | 12.6 | 17.0 | 26.3 | 38.0 | 52.8 ab |
| | F4 | 8.8 | 10.5 | 9.3 | 15.7 | 18.8 | 29.3 a | 10.2 | 12.1 | 14.4 | 19.5 | 26.8 | 35.2 a | 13.0 | 13.7 | 15.2 | 24.3 | 34.0 | 48.5 a |
| | NF | 16.9 | 23.6 | 24.3 | 32.8 | 37.3 | 43.8 bc | 16.3 | 24.0 | 26.5 | 37.3 | 44.3 | 48.5 b | 18.7 | 25.7 | 29.8 | 41.3 | 55.2 | 63.5 c |
| | CF | 21.8 | 25.5 | 31.8 | 50.5 | 55.1 | 67.7 e | 20.7 | 29.0 | 34.3 | 52.8 | 67.0 | 78.5 e | 27.2 | 32.8 | 44.0 | 55.8 | 78.0 | 86.5 e |
| | Treatment | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun | | | | | | |
| 2016 | S1 | 19.1 | 27.7 | 29.3 | 42.0 | 49.8 | 60.3 ef | 25.5 | 33.8 | 37.2 | 52.8 | 68.2 | 75.2 ce | | | | | | |
| | S2 | 18.3 | 23.5 | 26.2 | 37.8 | 41.5 | 54.3 cde | 22.0 | 30.2 | 34.0 | 47.3 | 61.2 | 74.0 bce | | | | | | |
| | S3 | 17.1 | 20.4 | 23.0 | 34.5 | 39.8 | 55.0 de | 21.5 | 30.2 | 33.2 | 48.7 | 63.0 | 78.5 ce | | | | | | |
| | S4 | 14.3 | 17.7 | 23.9 | 34.5 | 36.8 | 53.0 cde | 18.6 | 29.0 | 32.2 | 46.3 | 58.3 | 73.2 bcd | | | | | | |
| | F1 | 13.0 | 17.1 | 22.4 | 32.8 | 32.1 | 48.3 bd | 18.8 | 26.5 | 30.8 | 42.5 | 54.0 | 68.2 ac | | | | | | |
| | F2 | 10.0 | 13.8 | 18.5 | 26.3 | 32.7 | 44.7 bc | 17.2 | 23.3 | 29.3 | 40.5 | 51.0 | 65.7 ac | | | | | | |
| | F3 | 10.0 | 13.0 | 14.6 | 22.2 | 23.8 | 39.0 ab | 13.8 | 20.5 | 25.4 | 35.5 | 46.0 | 59.7 a | | | | | | |
| | F4 | 9.6 | 11.9 | 12.7 | 15.7 | 23.0 | 32.7 a | 14.1 | 21.2 | 26.5 | 36.5 | 48.5 | 61.7 ab | | | | | | |
| | NF | 13.3 | 24.3 | 26.7 | 38.8 | 43.5 | 48.7 bd | 21.0 | 29.8 | 31.8 | 41.3 | 52.2 | 57.0 a | | | | | | |
| | CF | 20.4 | 28.8 | 32.4 | 46.2 | 57.2 | 71.0 g | 25.0 | 35.8 | 40.3 | 56.0 | 73.3 | 86.5 e | | | | | | |

**Effects of compost on tiller number**

The means of tiller number of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of three repetitions in 2015 and two repetitions of 2016 are shown in Table 2.4 and Fig. 2.4.

In first repetition of 2015 (transplanted on 29 April), the tiller number of SSC treatments significantly differed throughout the plant growth, at 7 WAT the tiller number of control treatment CF was found to be significantly bigger (46) than SSC treatments. The tiller number of $S_1$ (33.5) registered the significantly maximum mean number of tillers among different levels of SSC throughout the survey period. The tiller numbers of $S_2$, and $S_3$ (32.5, and 25.7, respectively) were at par with treatment $S_1$. Tiller number of $S_4$ (19.3) was most depressed among SSC treatments in comparison to control treatment CF (c1 in Fig. 2.4). In second repetition of 2015 (transplanted on 13 May), the levels of SSC treatments did not significantly differ. However, control treatment CF recorded significantly higher number of tiller (49.7) and treatment NF registered significantly lower (13) than all SSC treatments (c3 in Fig. 2.4). In third repetition of 2015 (transplanted on 3 June), SSC treatments indicated the same tendency as second repetitions of 2015, the levels of SSC treatments did not significantly differ (c5 in Fig. 2.4).

In first repetition of 2016 (transplanted on 29 April), the tiller number of CF treatment was higher than all SSC treatments throughout the plant growth, at 7 WAT the tiller number of treatment $S_1$ (31.2) registered the significantly maximum mean number of tillers, treatment $S_4$ (19.3) was recorded lower and treatments $S_2$, and $S_3$ (32.5, and 25.7, respectively) were found at par with treatment $S_4$. Treatments $S_2$, and $S_3$ were even lower than treatment NF until 5 WAT (c7 in Fig. 2.4). In second repetition of 2016 (transplanted on 13 May), the levels of SSC treatments did not significantly differ. However, control treatment CF recorded significantly higher number of tiller (46.8) and treatment NF registered significantly lower (14.7) than all SSC treatments (c9 in Fig. 2.4).

In first repetition of 2015 (transplanted on 29 April), number of tiller was significantly decreased by increasing levels of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) until 7 WAT, the tiller number of treatment $F_1$ was found significantly higher (17.7) than other FWC treatments, the significantly lowest was registered in treatment $F_4$ (2.7) which was at par with treatments $F_2$, and $F_3$ (7.3 and 6.8, respectively) and treatment NF (10.7). The tiller number of FWC treatments were found to be significantly smaller than control treatments CF (46). All FWC treatments except $F_1$ were even significantly smaller than treatment NF (no fertilizer) until June $10^{th}$ (c2 in Fig. 2.4). In second repetition of 2015 (transplanted on 13 May), the tiller number was not significantly differ among levels of FWC during the initial plant growth but all FWC treatments were significantly inhibited. At 7 WAT the control treatments CF and NF (no fertilizer) recorded significantly highest tiller number (49.7 and 13, respectively) than all FWC treatments (c4 in Fig. 2.4). In third repetition of 2015 (transplanted on 3 June), FWC treatments indicated the same tendency as second repetition of 2015, the tiller number was not significantly differ among levels of FWC during the initial plant growth but all FWC treatments were significantly inhibited (c6 in Fig. 2.4).

In first repetition of 2016 (transplanted on 29 April), the tiller number of CF treatment was higher than all FWC treatments throughout the plant growth, tiller number of FWC treatments were even lower than treatment NF from 3 WAT to 7 WAT. At 7 WAT, among FWC treatments, the tiller number of treatment $F_1$ (14.7) registered the significantly maximum mean number of tillers, treatment $F_4$ (3.7) recorded the significantly lowest and treatments $F_2$, and $F_3$ (9.3, and 5.2, respectively) were found at par with treatment $F_4$ (c8 in Fig. 2.4). In second repetition of 2016 (transplanted on 13 May), treatment $F_1$ until 5 WAT, treatment $F_2$ until 6 WAT and treatment $F_3$ and $F_4$ until 7 WAT were lower than NF. At 7 WAT, the FWC treatments did not significantly differ among each other and all of them were found at par with treatment NF. However, control treatment CF recorded the significantly higher number of tiller (46.8) than all FWC treatments and NF (c10 in Fig. 2.4).

From the results of three repetitions in 2015 and two repetitions in 2016 (Table 2.4), it was determined that the third repetition (transplanted on June 3) was not significantly differ with second repetition (transplanted on May 13) however, first repetition (transplanted on April 29) in 2015 and 2016 was inhibited heavier than second and third repetitions. The tiller number depression caused by FWC was significantly more than SSC in all repetitions of 2015 and 2016 and the depression was increased by increasing levels of the composts, treatments $S_4$ and $F_4$ (high level of compost) were most depressed in comparison to control treatment CF and they were even smaller than NF (paddy soil condition with no fertilizer). All FWC treated plants were remained alive. Control treatment CF recorded higher tiller number than all SSC and FWC treatments.

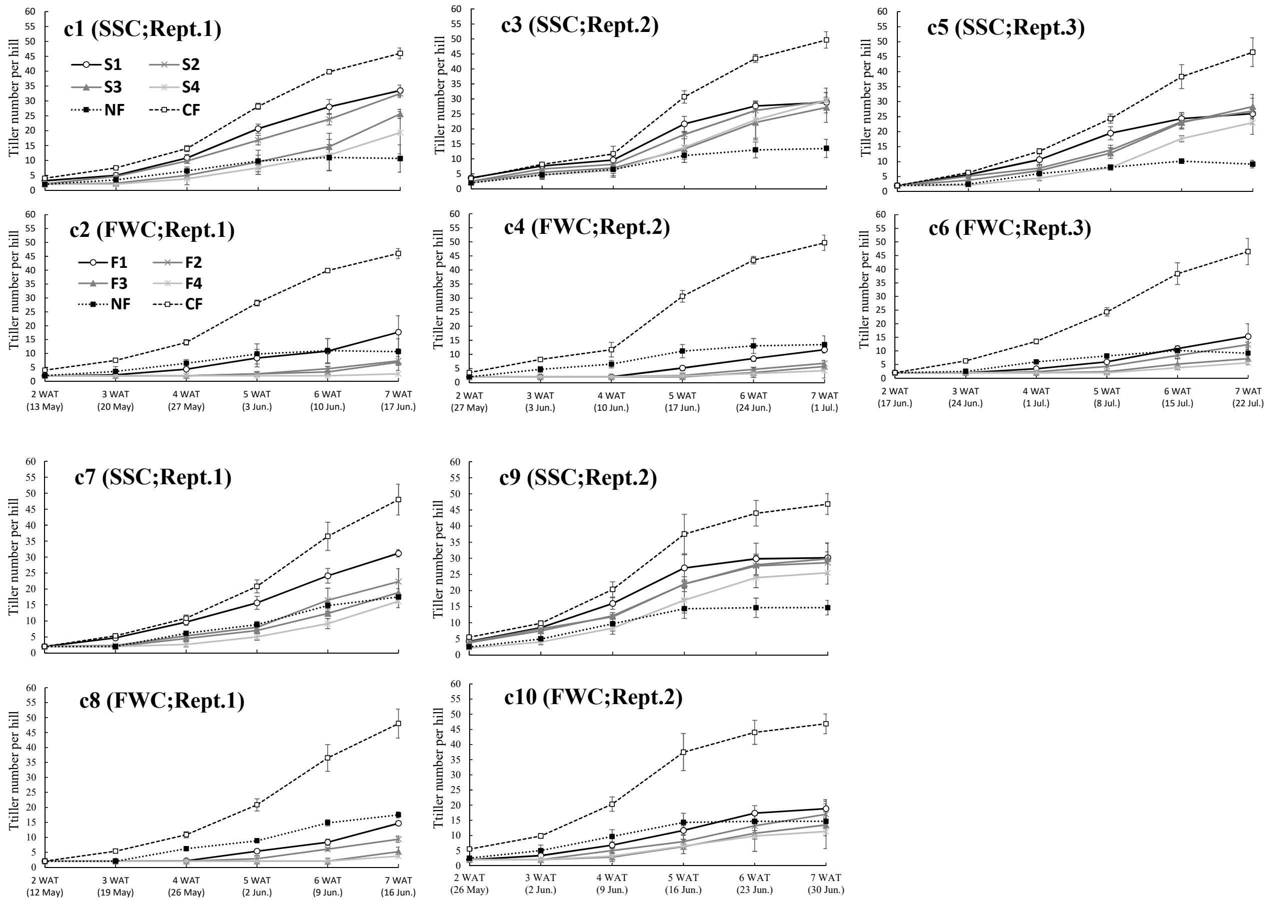



**Fig. 2.4 Effects of SSC and FWC application on tiller number at the early stage of rice plant in 2015 and 2016.**

c1-c6 show tiller number per hill in 2015. c7-c10 show tiller number per hill in 2016. First repetition of 2015 indicated in c1 and c2, second repetition in c3 and c4 and third repetition in c5 and c6. First repetition of 2016 indicated in c7 and c8 and second repetition in c9 and c10.

Data represent mean ± standard deviation (n = 3). Rept. means repetition. WAT: week after transplanting.

**Table 2.4 Tiller numbers per hill in 2015 and 2016.**

| Years | | First repetition | | | | | | Second repetition | | | | | | Third repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul |
| 2015 | S1 | 3.2 | 5.0 | 10.8 | 20.7 | 28.0 | 33.5 de | 3.7 | 7.7 | 9.7 | 21.7 | 27.7 | 28.8 c | 2.0 | 5.7 | 10.7 | 19.5 | 24.3 | 26.0 d |
| | S2 | 2.2 | 4.7 | 9.8 | 16.8 | 23.8 | 32.5 d | 2.5 | 6.7 | 8.2 | 18.2 | 26.2 | 29.3 c | 2.0 | 5.2 | 7.8 | 13.8 | 23.3 | 26.8 d |
| | S3 | 2.0 | 2.3 | 5.0 | 9.5 | 14.7 | 25.7 cd | 2.3 | 5.5 | 7.0 | 13.3 | 22.2 | 27.2 c | 2.0 | 3.8 | 7.0 | 12.8 | 23.0 | 28.3 de |
| | S4 | 2.0 | 2.0 | 3.8 | 7.5 | 11.8 | 19.3 bc | 2.2 | 4.7 | 6.2 | 13.8 | 23.0 | 29.5 c | 2.0 | 2.2 | 4.5 | 8.0 | 17.7 | 23.0 cd |
| | F1 | 2.0 | 2.3 | 4.3 | 8.3 | 10.8 | 17.7 bc | 2.0 | 2.0 | 2.0 | 5.2 | 8.5 | 11.7 ab | 2.0 | 2.0 | 3.5 | 6.0 | 10.8 | 15.3 bc |
| | F2 | 2.0 | 2.0 | 2.0 | 2.7 | 4.5 | 7.3 a | 2.0 | 2.0 | 2.0 | 2.5 | 4.7 | 6.8 ab | 2.0 | 2.0 | 2.3 | 4.3 | 8.3 | 12.3 ab |
| | F3 | 2.0 | 2.0 | 2.0 | 2.7 | 3.3 | 6.8 a | 2.0 | 2.0 | 2.0 | 2.0 | 3.5 | 5.7 ab | 2.0 | 2.0 | 2.0 | 2.3 | 5.2 | 7.2 ab |
| | F4 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.7 a | 2.0 | 2.0 | 2.0 | 2.3 | 3.2 | 4.2 a | 2.0 | 2.0 | 2.0 | 2.0 | 3.8 | 5.7 a |
| | NF | 2.0 | 3.5 | 6.5 | 9.8 | 11.0 | 10.7 ab | 2.0 | 4.7 | 6.5 | 11.2 | 13.3 | 13.0 b | 2.0 | 2.5 | 6.0 | 8.2 | 10.2 | 9.2 ab |
| | CF | 4.0 | 7.5 | 14.0 | 28.2 | 39.8 | 46.0 f | 3.5 | 8.2 | 11.7 | 30.7 | 43.5 | 49.7 d | 2.0 | 6.3 | 13.5 | 24.3 | 38.3 | 46.5 f |
| | Treatment | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun | | | | | | |
| 2016 | S1 | 2.0 | 4.7 | 9.7 | 15.7 | 24.2 | 31.2 e | 4.2 | 8.5 | 16.0 | 27.0 | 29.8 | 30.2 c | | | | | | |
| | S2 | 2.0 | 2.3 | 5.3 | 8.0 | 16.5 | 22.3 d | 4.0 | 8.2 | 11.8 | 22.0 | 27.7 | 28.7 c | | | | | | |
| | S3 | 2.0 | 2.0 | 4.5 | 7.0 | 12.3 | 18.8 cd | 3.8 | 7.5 | 12.2 | 22.0 | 28.0 | 29.8 c | | | | | | |
| | S4 | 2.0 | 2.0 | 2.7 | 5.0 | 9.2 | 16.2 bd | 2.2 | 4.0 | 8.3 | 17.0 | 24.0 | 25.5 bc | | | | | | |
| | F1 | 2.0 | 2.0 | 2.2 | 5.3 | 8.3 | 14.7 bc | 2.0 | 3.3 | 6.8 | 11.7 | 17.3 | 18.8 ac | | | | | | |
| | F2 | 2.0 | 2.0 | 2.0 | 2.8 | 6.0 | 9.3 ab | 2.0 | 2.0 | 5.0 | 8.0 | 13.2 | 17.0 ab | | | | | | |
| | F3 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 5.2 a | 2.0 | 2.0 | 2.8 | 6.3 | 10.7 | 13.5 a | | | | | | |
| | F4 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.7 a | 2.0 | 2.0 | 3.2 | 6.5 | 9.8 | 11.3 a | | | | | | |
| | NF | 2.0 | 2.0 | 6.2 | 8.8 | 14.8 | 17.5 cd | 2.5 | 5.0 | 9.7 | 14.3 | 14.7 | 14.7 ab | | | | | | |
| | CF | 2.0 | 5.3 | 10.8 | 20.8 | 36.5 | 48.0 f | 5.5 | 9.8 | 20.3 | 37.5 | 44.0 | 46.8 d | | | | | | |

**Soil pH**

The changes in submerged soil pH in each treatment from 1 to 7 WAT are shown in Table 2.5. At 7 WAT, the soil pH was not influenced by different levels of SSC and FWC treatments in three repetitions of 2015 and two repetitions of 2016. The soil pH values of SSC and FWC treatments were closed to neutral and increased numerically by increasing their levels in all repetitions. In the first repetition of 2015, treatments $S_4$ and $F_4$ (6.53 and 6.55, respectively) had highest pH value among the levels of SSC and FWC, while $S_1$ and $F_1$ were lower (6.33 and 6.38, respectively). The second and third repetitions of 2015, had the same tendency as first repetition. In second year (2016), similar trend was recorded, $S_4$ and $F_4$ had the highest value (6.05 and 6.17, respectively), while the least were in treatments $S_1$ and $F_1$ (5.90 and 5.99, respectively) in first repetition, and second repetition was shown the same as well. However, in comparison to CF treatments the soil pH of treatment CF was least than SSC and FWC treatments in all repetitions of 2015 and 2016, and soil pH was tended to be acidic at first WAT and gradually soil pH was increased up to 7 WAT (Table 2.5).

Table 2.5 Soil pH in 2015 and 2016.

| Years | | First repetition | | | | | | Second repetition | | | | | | Third repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatments | 8-May | 15-May | 22-May | 29-May | 5-Jun | 12-Jun | 22-May | 29-May | 5-Jun | 12-Jun | 19-Jun | 26-Jun | 12-Jun | 19-Jun | 26-Jun | 3-Jul | 10-Jul | 17-Jul |
| 2015 | S1 | 6.20 | 6.14 | 5.90 | 5.70 | 6.43 | 6.33 | 6.74 | 6.13 | 6.57 | 6.43 | 6.34 | 6.27 | 6.98 | 6.38 | 6.86 | 6.24 | 6.15 | 6.25 |
| | S2 | 6.56 | 6.65 | 6.29 | 5.82 | 6.48 | 6.36 | 6.75 | 6.40 | 6.78 | 6.63 | 6.45 | 6.63 | 6.95 | 6.22 | 6.42 | 6.12 | 6.25 | 6.38 |
| | S3 | 6.44 | 7.13 | 6.24 | 6.10 | 6.73 | 6.44 | 7.20 | 6.55 | 7.00 | 6.81 | 6.51 | 6.49 | 7.21 | 6.88 | 6.65 | 6.49 | 6.40 | 6.50 |
| | S4 | 6.75 | 6.75 | 6.42 | 6.22 | 6.62 | 6.53 | 6.80 | 6.87 | 6.73 | 6.63 | 6.53 | 6.37 | 7.59 | 6.84 | 6.65 | 6.65 | 6.58 | 6.51 |
| | F1 | 6.60 | 6.70 | 6.34 | 6.14 | 6.52 | 6.38 | 6.69 | 6.63 | 6.68 | 6.47 | 6.38 | 6.80 | 6.46 | 6.34 | 6.45 | 6.48 | 6.42 | 6.50 |
| | F2 | 6.64 | 6.76 | 6.36 | 6.16 | 6.51 | 6.41 | 6.67 | 6.55 | 6.83 | 6.55 | 6.53 | 6.71 | 6.46 | 6.40 | 6.47 | 6.50 | 6.59 | 6.41 |
| | F3 | 6.61 | 6.78 | 6.31 | 6.18 | 6.55 | 6.39 | 6.76 | 6.71 | 6.87 | 6.68 | 6.48 | 6.71 | 6.55 | 6.50 | 6.59 | 6.50 | 6.50 | 6.55 |
| | F4 | 6.55 | 6.49 | 6.26 | 6.03 | 6.76 | 6.55 | 6.74 | 6.67 | 6.74 | 6.55 | 6.51 | 6.47 | 6.48 | 6.29 | 6.40 | 6.48 | 6.46 | 6.39 |
| | NF | 6.32 | 6.79 | 6.27 | 5.97 | 6.47 | 6.44 | 6.83 | 5.99 | 6.69 | 6.44 | 6.12 | 6.30 | 6.95 | 6.39 | 6.32 | 6.01 | 5.71 | 6.10 |
| | CF | 4.68 | 4.76 | 4.55 | 4.54 | 5.49 | 5.98 | 5.85 | 4.38 | 4.85 | 5.02 | 4.71 | 5.80 | 6.38 | 4.54 | 4.44 | 4.45 | 4.59 | 5.86 |
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | | | | | | |
| 2016 | S1 | 5.97 | 5.70 | 6.26 | 6.12 | 5.90 | 6.17 | 5.70 | 6.13 | 5.97 | 5.92 | 5.98 | N/A | | | | | | |
| | S2 | 6.38 | 6.10 | 6.32 | 6.14 | 5.91 | 6.20 | 6.10 | 6.28 | 6.37 | 6.06 | 6.13 | N/A | | | | | | |
| | S3 | 6.30 | 6.08 | 6.34 | 6.11 | 6.04 | 6.18 | 6.08 | 6.33 | 6.25 | 6.06 | 6.15 | N/A | | | | | | |
| | S4 | 6.41 | 6.11 | 6.42 | 6.20 | 6.05 | 6.11 | 6.11 | 6.34 | 6.29 | 6.17 | 6.22 | N/A | | | | | | |
| | F1 | 6.38 | 6.13 | 6.44 | 6.18 | 5.99 | 6.15 | 6.13 | 6.43 | 6.21 | 6.10 | 6.26 | N/A | | | | | | |
| | F2 | 6.50 | 6.23 | 6.42 | 6.17 | 6.10 | 6.24 | 6.23 | 6.18 | 6.30 | 6.15 | 6.28 | N/A | | | | | | |
| | F3 | 6.53 | 6.23 | 6.38 | 6.17 | 6.04 | 6.36 | 6.23 | 6.42 | 6.26 | 6.18 | 6.23 | N/A | | | | | | |
| | F4 | 6.33 | 6.13 | 6.34 | 6.22 | 6.17 | 6.35 | 6.13 | 6.44 | 6.22 | 6.19 | 6.35 | N/A | | | | | | |
| | NF | 6.26 | 5.58 | 6.06 | 5.84 | 5.63 | 6.01 | 5.58 | 5.56 | 5.66 | 5.50 | 5.88 | N/A | | | | | | |
| | CF | 4.83 | 5.08 | 5.37 | 5.36 | 4.59 | 5.47 | 5.08 | 5.48 | 5.07 | 4.70 | 5.22 | N/A | | | | | | |

N/A: Data not available.

## 2. Effects of compost on dry matter production

The means dry matter production of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) sampled from three repetitions in 2015 and two repetitions in 2016 are shown in Table 2.6 and Table 2.7.

It was found from the result of this study that application of SSC and FWC with their levels obviously effect on dry matter production of rice. In general, dry weight of root, leaf sheath, leaf blade, top and T-R ratio were differ by different composts (SSC and FWC) and their levels.

In first repetition of 2015 (sampled on June 17), at 7 WAT, the dry weight of leaf blade, leaf sheath, top and root of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their levels. The significantly ($P$<0.05) high dry weight of leaf blade, leaf sheath, top and root was found in treatments $S_1$ (5.54, 6.6, 12.2 and 3.3 g, respectively) which were at par with treatment $S_2$ (4.9, 5.3, 10.2 and 3.2 g, respectively) and the significantly minimum was recorded in treatments $S_4$ (2.2, 2.5, 4.7 and 1.4 g, respectively) which were at par with treatments $S_3$ (3.1, 3.1, 6.2 and 1.6 g, respectively) and NF (1.1, 2.0, 3.1 and 1.3 g, respectively). Control treatment CF registered significantly maximum dry weight of leaf blade, leaf sheath and top (8.9, 9.4 and 18.3 g, respectively) but the root dry weight of treatment CF (2.6 g) was at par with all SSC treatments other than treatment $S_4$. The T-R ratio of CF treatment (7.1) was significantly larger than all SSC treatments and NF, however the T-R ratio of all SSC treatments and NF were at par with each other (Table 2.6). In second repetition of 2015 (sampled on July 1), the dry weight of leaf blade, leaf sheath, top and root of SSC treatments did not significantly differ among different levels of SSC except treatment

$S_1$ which was higher than the others. The dry weight of leaf blade, leaf sheath, top and root of SSC treatments were depressed in comparison to control treatment CF. The T-R ratio of all SSC treatments and CF treatment (5.3) were found at par with each other, however the T-R ratio of NF (2.0) treatment was significantly lower than them. In third repetition of 2015 (sampled on July 22), the dry weight of leaf blade, leaf sheath, top and root of SSC treatments did not significantly differ among different levels of SSC except treatment $S_4$ which was significantly lower than rest of treatments. Dry weight of leaf blade, leaf sheath, top and root of control treatment CF was found significantly higher than all SSC treatments but all SSC treatments produced heavier dry weight than NF. Root dry weight of treatments $S_1$ was equal to treatment CF. The T-R ratio of CF treatment (4.4) was significantly at par with all SSC treatments and NF. (Table 2.6).

In first repetition of 2016 (sampled on June 23), at 8 WAT, the leaf blade, leaf sheath, top and root dry weight of SSC treatments decreased by increasing their levels. The high dry weight of leaf blade, leaf sheath, top and root was found in treatments $S_1$ (7.0, 7.2, 14.2 and 2.9 g, respectively) and the minimum was recorded in treatments $S_4$ (3.8, 3.6, 7.4 and 1.3 g, respectively) which was at par with treatments $S_2$, $S_3$, and NF. Control treatment CF registered significant maximum dry weight of leaf blade, leaf sheath, top and root (13.0, 13.6, 26.6 and 3.6 g, respectively). The T-R ratio of all SSC treatments except treatment $S_1$ were at par with CF treatment (7.5), however the T-R ratio of treatments NF (2.9) and $S_1$ (4.8) were significantly lower than CF (Table. 2.7). In second repetition of 2016 (sampled on July 7), the dry weight of leaf blade, leaf sheath and top of SSC treatments did not significantly differ among different levels of SSC. Root dry weight of treatment $S_1$ (4.8) which was at par with $S_2$ (3.6) recorded significantly lower than treatments $S_3$ and $S_4$ (1.5 and 1.3, respectively). The dry weight of leaf blade, leaf sheath, top and root of SSC treatments were depressed in comparison to control treatment CF. The T-R ratio of treatment $S_1$ (5.6) which was at par with treatments $S_2$ and NF (6.8 and 3.3, respectively) found significantly lower than treatments $S_3$, $S_4$ and CF (8.0, 7.8 and 8.3, respectively) (Table. 2.7).

In first repetition of 2015 (sampled on June 17), at 7 WAT, the dry weight of leaf blade, leaf sheath, top and root of FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$) was not significantly differ among different levels of FWC except treatment $F_1$ which produced the highest. Control treatment CF recorded significantly higher of leaf blade, leaf sheath, top and root dry weight than all FWC treatments however, treatment NF (paddy soil condition with no fertilizer) was at par with all FWC treatments. The T-R ratio of CF treatment (7.1) was significantly larger than all FWC treatments and NF, however the T-R ratio of all FWC treatments and NF were at par with each other (Table 2.6). In second repetition of 2015 (sampled on July 1), the dry weight of leaf blade, leaf sheath and root were not significantly differ among different levels of FWC. Top dry weight of treatment F1 was recorded higher than rest of FWC treatments. Control treatment CF counted significantly higher leaf blade, leaf sheath, top, and root dry weight than all FWC treatments. The T-R ratio of all FWC treatments and NF were found at par with each other but lower than CF (Table 2.6). In third repetition of 2015 (sampled on July 22), FWC treatments indicated the same tendency as second repetitions of 2015. (Table 2.6).

In first repetition of 2016 (sampled on June 23), at 8 WAT, the dry weight of leaf blade, leaf sheath, top and root of FWC treatments was found significantly high in treatment $F_1$ (2.8, 2.8, 5.5 and 1.2 g, respectively) which was at pat with treatment NF, and the significant minimum was found in treatments $F_4$ (0.4, 0.4, 0.8 and 0.2 g, respectively) which was at pat with treatments $F_2$ and $F_3$. Control treatment CF recorded significantly higher (13.0, 13.6, 26.6 and 3.6 g, respectively) than all FWC treatments. The T-R ratio of all FWC treatments and NF were found at par with each other but lower than CF (Table 2.7). In second repetition of 2016 (sampled on July 7), the dry weight of leaf blade, leaf sheath, top and root was not significantly differ among different levels of FWC. Treatment NF was found at par with all FWC treatments. However, control treatment CF recorded significantly higher than FWC treatments. The T-R ratio of all FWC treatments and NF were at par with each other, the T-R ratio of treatments $F_2$ and $F_3$ was even equal to control treatment CF (Table 2.7).

From the results of three repetitions in 2015 and two repetitions in 2016, it was found that the dry matter production (dry weight of leaf blade, leaf sheath, top and root) of third repetition (transplanted on June 3) was higher than second (transplanted on May 13) and first (transplanted on April 29) repetitions, and the first repetition was inhibited heavier than second and third repetitions. The dry matter production were depressed by application of SSC and FWC at the early growth stage and the depression was increased by increasing the amount of compost. The depression within each repetition was the same as the other repetitions but the degree of depression of different repetitions was differ. FWC treatments caused greater depression than SSC treatments in three repetitions of 2015 and two repetitions of 2016.

**Table 2.6 Dry matter production (g hill$^{-1}$) at early growth stage in 2015.**

| Repe-tition | Trea-tments | L.B**** | L.S*** | Top (g hill$^{-1}$) | Root (g hill$^{-1}$) | T-R ratio** |
|---|---|---|---|---|---|---|
| | **S1** | 5.5 c | 6.6 c | 12.2 c | 3.3 b | 3.8 a |
| | **S2** | 4.9 c | 5.3 c | 10.2 c | 3.2 b | 3.3 a |
| | **S3** | 3.1 b | 3.1 b | 6.2 b | 1.6 ab | 3.8 a |
| | **S4** | 2.2 b | 2.5 b | 4.7 b | 1.4 a | 3.4 a |
| **First** | **F1** | 2.0 b | 2.4 b | 4.4 b | 1.9 b | 3.0 a |
| (17 June)* | **F2** | 0.5 a | 0.5 a | 1.0 a | 0.3 a | 3.0 a |
| | **F3** | 0.5 a | 0.6 a | 1.1 a | 0.4 a | 3.1 a |
| | **F4** | 0.1 a | 0.1 a | 0.3 a | 0.1 a | 2.2 a |
| | **NF** | 1.1 ab | 2.0 ab | 3.1 ab | 1.3 a | 2.5 a |
| | **CF** | 8.9 d | 9.4 d | 18.3 d | 2.6 b | 7.1 b |
| | **S1** | 6.2 b | 7.5 d | 13.7 d | 3.6 c | 3.9 bc |
| | **S2** | 5.8 b | 6.2 cd | 12.0 cd | 2.9 bc | 4.2 c |
| | **S3** | 4. 6 b | 4.5 c | 9.1 c | 2.5 b | 3.7 bc |
| | **S4** | 5.2 b | 5.0 c | 10.2 cd | 2.5 b | 4.1 c |
| **Second** | **F1** | 1.2 a | 1.4 ab | 2.6 b | 0.8 a | 3.2 ab |
| (1 July)* | **F2** | 0. 6 a | 0.6 a | 1.2 ab | 0.4 a | 3.1 ab |
| | **F3** | 0.4 a | 0.4 a | 0.7 a | 0.2 a | 3.5 ab |
| | **F4** | 0.3 a | 0.3 a | 0.7 a | 0.2 a | 2.4 ab |
| | **NF** | 1.8 a | 2.6 b | 4.4 b | 2.2 b | 2.0 a |
| | **CF** | 10.7 c | 11.3 e | 22.0 e | 4.1 c | 5.3 c |
| | **S1** | 8.1 d | 9.8 d | 17.9 d | 5.0 b | 3.6 ab |
| | **S2** | 7.2 cd | 7.8 d | 15.0 cd | 3.4 b | 4.4 ab |
| | **S3** | 7.7 d | 8.2 d | 15.9 d | 3.5 b | 4.5 ab |
| | **S4** | 5.6 c | 5.7 c | 11.2 c | 2.2 a | 5.0 b |
| **Third** | **F1** | 2.5 b | 2.7 b | 5.2 b | 1.1 a | 4.6 ab |
| (22 July)* | **F2** | 1.7 ab | 1.8 ab | 3.6 ab | 0.8 a | 4.5 ab |
| | **F3** | 0.7 ab | 0.7 a | 1.3 ab | 0.3 a | 4.0 ab |
| | **F4** | 0.5 a | 0.5 a | 1.0 a | 0.3 a | 3.2 a |
| | **NF** | 1.9 ab | 2.9 b | 4.8 ab | 1.4 a | 3.6 ab |
| | **CF** | 14.6 e | 16.3 e | 30.9 e | 7.5 c | 4.4 ab |

**** Leaf Blade. *** Leaf Sheath. ** The Top-Root ratio. * Date of sampling.
Data represent mean (n=3). Means within each column with the same letter(s) are not significantly different at *P*<0.05, using Tukey multiple comparisons test.

**Table 2.7 Dry matter production (g hill$^{-1}$) at early growth stage in 2016.**

| Repe- tition | Trea- tments | L.B**** | L.S*** | Top (g hill$^{-1}$) | Root (g hill$^{-1}$) | T-R ratio** |
|---|---|---|---|---|---|---|
| | $S_1$ | 7.0 d | 7.2 d | 14.2 d | 2.9 cd | 4.8 ab |
| | $S_2$ | 5.1 c | 4.9 c | 10.0 c | 1.7 b | 5.9 bc |
| | $S_3$ | 4.5 c | 4.3 bc | 8.8 bc | 1.5 b | 5.7 bc |
| | $S_4$ | 3.8 bc | 3.6 bc | 7.4 bc | 1.3 b | 5.7 bc |
| **First** | $F_1$ | 2.8 b | 2.8 b | 5.5 b | 1.2 ab | 4.5 ab |
| (23 June)* | $F_2$ | 1.7 ab | 1.6 ab | 3.3 ab | 0.7 ab | 4.5 ab |
| | $F_3$ | 0.7 a | 0.6 a | 1.3 a | 0.4 a | 3.5 a |
| | $F_4$ | 0.4 a | 0.4 a | 0.8 a | 0.2 a | 4.8 ab |
| | **NF** | 2.6 b | 4.4 b | 7.0 b | 2.4 c | 2.9 a |
| | **CF** | 13.0 e | 13.6 e | 26.6 e | 3.6 d | 7.5 c |
| | $S_1$ | 10.6 b | 16.4 b | 27.0 b | 4.8 b | 5.6 ab |
| | $S_2$ | 11.0 b | 13.4 b | 24.4 b | 3.6 b | 6.8 bc |
| | $S_3$ | 11.3 b | 12.6 b | 23.9 b | 3.0 a | 8.0 c |
| | $S_4$ | 9.6 b | 11.1 b | 20.7 b | 2.6 a | 7.8 c |
| **Second** | $F_1$ | 5.7 a | 8.7 a | 14.4 a | 2.9 a | 5.0 ab |
| (07 July)* | $F_2$ | 5.1 a | 6.4 a | 11.5 a | 1.8 a | 6.2 abc |
| | $F_3$ | 4.3 a | 5.2 a | 9.6 a | 1.3 a | 7.1 bc |
| | $F_4$ | 2.9 a | 3.3 a | 6.3 a | 1.1 a | 5.9 ab |
| | **NF** | 3.1 a | 6.1 a | 9.2 a | 2.8 a | 3.3 a |
| | **CF** | 19.6 c | 26.2 c | 45.9 c | 5.5 b | 8.3 c |

**** Leaf Blade. *** Leaf Sheath. ** The Top-Root ratio. * Date of sampling.
Data represent mean (n=3). Means within each column with the same letter(s) are not significantly different at $P<0.05$, using Tukey multiple comparisons test.

The results of the analysis of variance (ANOVA), which analyzed the effects of compost on dry matter productions of three repetitions in 2015 are shown in Table 2.8.

The dry weight of leaf blade, leaf sheath, top and root were significantly ($P<0.05$) differed by compost types (SSC and FWC), different N levels and three repetitions. The significantly maximum dry matter of leaf blade, leaf sheath, top and root (5.5, 6.0, 11.5 and 2.9 g, respectively) was recorded with SSC, and the significantly minimum (0.9, 1.0, 1.9 and 0.6 g, respectively) registered with FWC. Lower levels of compost produced heavier dry matter than higher levels. Increase in the N levels of the composts from 16.5 to 22 g N pot-1 resulted in a significant decrease in dry matter production. The first repetition (popular transplanting date in Mie prefecture, Japan) recorded significantly lower dry matter production than later transplanting dates (second and third). In Japan, rice transplanting time has been starting earlier over the past 50 years. It is severe problem that compost application depressed the early growth of rice plants while the spring temperatures are low.

**Table 2.8 ANOVA of the effects of compost on dry matter production in 2015.**

| **Source of variation** | **Leaf blade** | **Leaf sheath** | **Top** | **Root** |
|---|---|---|---|---|
| Compost types (T) | ** | ** | ** | ** |
| Nitrogen levels (A) | ** | ** | ** | ** |
| Repetitions (R) | ** | ** | ** | ** |
| Block (B) | | | | |
| T x A | * | ** | ** | * |
| T x R | ** | ** | ** | ** |
| T x B | | | | |
| A x R | * | * | * | |
| A x B | | | | |
| R x B | ** | ** | ** | |
| T x A x R | * | ** | ** | |
| T x A x B | | | | |
| T x R x B | * | * | * | |
| A x R x B | | | | |

** Significant at 0.01 level of probability. * Significant at 0.05 level of probability.

| **Multiple compression** | | | | |
|---|---|---|---|---|
| T | | | | |
| SSC | 5.5 b | 6.0 b | 11.5 b | 2.9 b |
| FWC | 0.9 a | 1.0 a | 1.9 a | 0.6 a |
| A | | | | |
| 5.5 g | 4.3 c | 5.1 c | 9.3 c | 2.6 c |
| 11 g | 3.4 b | 3.7 b | 7.1 b | 1.8 b |
| 16.5 g | 2.8 a | 2.9 a | 5.7 a | 1.4 ab |
| 22 g | 2.3 a | 2.4 a | 4.7 a | 1.1 a |
| R | | | | |
| First repetition | 2.4 a | 2.6 a | 5.0 a | 1.5 a |
| Second repetition | 3.0 b | 3.2 b | 6.3 b | 1.6 a |
| Third repetition | 4.2 c | 4.6 c | 8.9 c | 2.1 b |
| B | | | | |
| Block 1 | 3.3 a | 3.5 a | 6.7 a | 1.8 a |
| Block 2 | 3.1 a | 3.4 a | 6.5 a | 1.7 a |
| Block 3 | 3.3 a | 3.6 a | 6.7 a | 1.8 a |

Means within each column with the same letter(s) are not significantly different at $P<0.05$, using Tukey multiple comparisons test.

## Discussion

The results of experiment have been presented in preceding topics. They are required to be discussed in the light of scientific knowledge and principles of Agronomy. Interpretations have been made in the view of the factors governing the manifestation of result and their corroboration light of results obtained by other scientist workers engaged in the relative field of research. The result of this study show significant effects of application of SSC and FWC with their levels and time of transplanting on initial growth stage of rice plants.

### Growth characters

The growth parameters (leaf emergence pattern, plant length and tiller number) were inhibited by SSC and FWC application and the depression was increased by increasing levels of the composts. Depression caused by FWC was heavier than SSC in all repetitions. The first repetition was inhibited more than second and third repetitions. The decrease in growth parameters at the early stage caused by increasing the levels of SSC and FWC application might be due to the rate of decomposition and the mineralization process of compost which caused immobilization of nutrients. The immobilization of nutrient especially nitrogen in all compost treated soils was reported by Vanlauwe *et al.*, (1998) which most of the soil nitrogen was held in organic form. Based on visual observation, compost application by its microbial activities and decomposing process caused an abnormal condition in the soil by putrefying soil and water, changing their color, smell and temperature at the initial growth stage. This condition might prevent root growth and development at the early growth stage particularly initial roots, and rice plants which were sensitive at this stage could not uptake nutrients and grew properly. Therefore, the higher amount of compost (N levels) applied produced the lower growth parameters (Figs. 2.2-2.4). Abe, *et al*., (1995) reported that the application of castor meal two weeks before transplanting as basal dressing resulted in the dying off of most of the leaves, and markedly inhibited root growth at seedling stage and the magnitude of the damage were depend on the amount of organic material applied.

The heavier inhibition effects of FWC than SSC in each repetition at early growth stage (Tables 2.2-2.4) might be due to microbial activities in soil, compost ingredients, method of composting and aromatic acid. FWC was prepared under aerobic conditions, by which it was situated in a water flooded condition, FWC started putrefying soil and water and they got bad smile with green color and created undesirable satiation for plant growth. It was also described by Tanaka and Ono, (2000) that decrease in the redox potential of soil following harmful metabolite production during soil microbial fermentation under anaerobic conditions. As well. Tanaka and Ono, (2000) reported in a pot experiment with different organic matters that rice seedling growth was inhibited by application of the same organic matter that led to the accumulation of aromatic acids in the soil.

The intensity of inhibition effects of SSC and FWC in the first repetition (transplanted on April 29) than those transplanted later (second and third repetitions) might be due to low air and soil temperature and consequence of low decomposition rate of compost.

**Dry matter production**

Dry matter productions (dry weight of leaf blade, leaf sheath, top and root) were depressed by application of SSC and FWC at the early growth stage and the depression was increased by increasing the amount of compost. FWC treatments caused greater depression than SSC treatments in all repetitions. The first repetition which transplanted on April 29 was inhibited heavier than second and third repetitions. The decreases in dry weight of root, leaf sheath, leaf blade and top by increasing N levels (amount) of SSC and FWC at the early growth stage are not only due to the unavailability of nutrients but also possibly a result of the microbiological activities of compost, enzyme activity and biomass specific respiration in the soil. Albiach *et al.*, (2000) reported that annual application of organic residues, municipal solid waste, bovine manure and sewage sludge, led to significant increase of soil enzyme activities. Zaman *et al.*, 2002 reported in an experiment on different soil that the application of SSC increase microbial biomass and activity in soil. Aoyama *et al.*, (2006) described that the application of lime-treated sewage sludge compost not only increased soil respiration but also biomass specific respiration. Indeed, the rice root has $O_2$ releasing and oxidizing ability, but higher microbial biomass and respiration led to higher cumulative $CO_2$ in soil which retarding the root growth and development. The low levels of both composts produced high root dry weight, and the treatments with high root dry weight recorded high top dry weight as well (Tables 2.6 and 2.7). The growth and development of roots are assumed to mutually interact with top. Osaki *et al.*, (1997) also reported that high photosynthetic rate of shoots secures high root activity by supplying a sufficient amount of photosynthates to the roots. Conversely, high root activity secures a high photosynthetic rate by supplying a sufficient amount of nutrients to shoot, so ensures high productivity.

In Japan, rice transplanting time has been starting earlier over the past 50 years, early-season cultivation of rice plant was carried out in Mie prefecture by using main cultivar Koshihikari. (Mie 2015). The early transplanting of rice plants was inhibited at initial growth stage heavier than late transplanting, which was a severe problem that basal composts (SSC and FWC) application created (Table 2.8) this might be due to air and soil temperature.

## Conclusions

It is concluded from the results of five repetitions in two years that the basal application of FWC and SSC had inhibiting effects on growth parameters and dry matter production at the early growth stage of rice plants. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effect of FWC was heavier than that SSC. It is important to consider the amount and material of organic compost to avoid severe depression in the early growth stage. Early transplanting inhibited the initial growth of rice plant by basal application of SSC and FWC therefore, it is important to investigate more to reduce the inhibition effects of SSC and FWC for improving growth and yield of rice plant.

* * *

# Chapter Four

## Effects of different application methods of different composts (SSC and FWC) on the growth and yield of rice (*Oryza sativa* L.)

In the previous experiments, the FWC and SSC which produced from cyclical food resources, such as food waste, food processing residues and sewage sludge from food factories, wood chips, and grass clippings were applied as basal fertilizer application on rice plants. It was reported that the basal application of FWC and SSC had inhibiting effects on growth parameters (leaf emergence pattern, plant length and tiller number) and dry matter production (dry weight of leaf blade, leaf sheath, top and root) at the early growth stage of rice plants. Slower leaf emergence, fewer tiller numbers, shorter plant length, lower dry weight of leaf blade, leaf sheath, top and root, and delayed heading were caused by SSC and FWC application. The degree of inhibition was increased by increasing the amount of composts at the early growth stage while it was reduced at the late stage. The inhibition effects of FWC was heavier than that SSC at the early growth stage of rice plant. The early transplanting, inhibited the initial growth of rice plant by basal application of SSC and FWC heavier than late transplanting. Nagaya *et al*. (2013) has been reported the depression in growth at the early stage in a pot experiment using SSC-like compost with three different nitrogen levels. Nishikawa *et al*., (2013) also reported in his field experiment that application of anaerobically-digested manure has temporal inhibition effect on growth parameters of rice plants, from transplanting to the active tillering stage compared to chemical fertilizer.

In the previous experiments, it has been also explained that no significant differences in yield were observed among standard level of chemical fertilizer (CF) treatment and levels of compost, except low level (5.5 g Nitrogen per 24 L pot) which produced lower yield, other levels (11, 16.5 and 22 g N $pot^{-1}$) were found at par to each other in yield. Watanabe *et al*.,

(2011) and Nishikawa *et al*., (2013) reported the inhibition effects at initial growth by anaerobically-digested cattle manure caused a serious yield decline under some cropping conditions depending on soil type, rice cultivar, fertilization and water management.

We expected from the result of our previous experiments that if we could reduce the inhibition effects at the early growth stage of rice plant which caused by application of compost, we might be able to increase the yield of rice. Therefore, we believe that different transplanting time and different methods of fertilizer application are options for solving the inhibition effects of SSC and FWC application at the early growth stage. Goto *et al*., (2006) reported that the surface layer application method of nitrogen reduced the recovery rate and yield in rice plant, but side dressing incorporation into the plow layer could be a valuable method for the production of low protein-content rice in high yield. The side dressing of FWC and SSC is a new method of basal dressing to rice plants. With this method, we might promote the initial growth, save labour for fertilizer application, and increase fertilizer use efficiency. Basal FWC and SSC are applied and mixed with $1/6^{th}$ part of one pot's soil in a line, at the depth of 20 cm and 7-8 cm aside from rice seedlings.

In the light of the above viewpoints, it is planned to investigate and find a way to solve the problem of inhibition effects of SSC and FWC application on rice plants at the early growth stage and improve rice yield with different time of transplanting and different methods of compost application.

## Materials and Methods

The present investigation entitled "Effects of different application methods of different composts (SSC and FWC) on the growth and yield of rice (*Oryza sativa* L.)" was conducted during 2016-2017 for two years. The details about the climatic under which the present investigation was carried out, experimental material used, techniques employed and criteria for evaluation of treatments during the course of investigation have been described as below.

### 1. Site description

The two years pot experiments were conducted at the Experimental Field of Mie University, Mie, Japan on 2016 and 2017, which is geographically located in Tsu city in the Kansai region on the island of Honshu in the central part of Japan, at latitude 34° 43′ 6.96″ North and longitude 136° 30′ 20.51″ East with an elevation of about 2 meters above mean sea level. Tsu city has a humid subtropical climate with hot summers and cool winters. Precipitation is significant throughout the year, but is heaviest from May to September.

The every 10 days mean weather data such as 10 days average temperature (°C) and total rainfall (mm) during the crop seasons from April 1$^{st}$ to the end of September 2016 and 2017 were recorded from local meteorological observatory located in Tsu city.

### Composting process

The composting process is the same as explained in first experiment (refer to chapter second, page 9) and chemical and physical characteristics of the composts are shown in Table 3.1.

**Table 3.1 Chemical and physical properties of composts.**

| | SSC | FWC |
|---|---|---|
| C (total carbon) (g $Kg^{-1}$) | 346.0 | 366.0 |
| N (total nitrogen) (g $Kg^{-1}$) | 61.0 | 46.0 |
| C/N Ratio | 5.7 | 7.8 |
| pH ($H_2O$, 1:10) | 6.8 | 7.2 |
| Electrical Conductivity (mS/$cm^{-1}$) | 8.4 | 5.9 |
| $P_2O_5$ (g $Kg^{-1}$) | 31.0 | 17.0 |
| $K_2O$ (g $Kg^{-1}$) | 18.9 | 15.9 |
| Moisture (%) | 31.6 | 30.6 |

Concentration is expressed as dry basis.
Sampling day of compost was 1st April, 2017.

**Treatments and experimental design**

The pot experiments were arranged in randomized block design (RBD) with 3 replications and repeated three times (2 repetitions in 2016 and 1 repetition in 2017) under open field condition. Repetition of the experiment is act of cultivation and transplanting of rice plants in different dates in the same year. Two different times of transplanting in 2016 and one time of transplanting in 2017, hereafter each time of transplanting referred to as "repetition". In 2016, the growth parameters and dry matter production and in 2017, the growth parameter and yield components were investigated. The containers (24 L) with dimensions of 46.4 cm (length) × 23.4 cm (width) × 22 cm (height) were used as pot in these experiments. Treatments included two types of compost (SSC and FWC), each with four nitrogen (N) levels (5.5, 11.0, 16.5 and 22.0 g N pot$^{-}$1), applied with two methods of application: side dressing (SD) and uniform application of fertilizer to the topsoil (uniform application), chemical fertilizer (CF) at standard level (6.1 g N pot$^{-1}$) as control treatment and no fertilizer (NF) was used to know the degree of soil fertility. Cultivated two times in 2016 and one times in 2017.

The 18 treatments' names were abbreviated as $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD for SSC; $F_1$SD, $F_2$SD, $F_3$SD, and $F_4$SD for FWC which were applied at one side and $S_1$, $S_2$, $S_3$ and $S_4$ for SSC; $F_1$, $F_2$, $F_3$, and $F_4$ for FWC which were applied uniformly, CF for standard level of CF and NF for no fertilizer. The N content per pot of $S_1$SD, $F_1$SD, $S_1$ and $F_1$ was 5.5 g; $S_2$SD, $F_2$SD, $S_2$ and $F_2$ was 11 g; $S_3$SD, $F_3$SD, $S_3$ and $F_3$ was 16.5 g; $S_4$SD, $F_4$SD, $S_4$ and $F_4$ was 22 g; CF was 6.1 g and NF was 0 g (Table 3.2). The amount of compost for each SSC and FWC treatments was determined based on the N level of each treatment.

**Table 3.2 Treatments and total nitrogen (N), $P_2O_5$ and $K_2O$ levels.**

| Treatments | | Source of nutrients | Total Nitrogen per pot (g) | $P_2O_5$ per pot (g) | $K_2O$ per pot (g) |
|---|---|---|---|---|---|
| Uniform application* | Side dressing | | | | |
| **$S_1$** | **$S_1$SD** | Sewage | 5.5 | 2.8 | 1.7 |
| **$S_2$** | **$S_2$SD** | Sludge | 11.0 | 5.6 | 3.4 |
| **$S_3$** | **$S_3$SD** | Compost | 16.5 | 8.4 | 5.1 |
| **$S_4$** | **$S_4$SD** | (SSC) | 22.0 | 11.2 | 6.8 |
| **$F_1$** | **$F_1$SD** | Food | 5.5 | 2.0 | 1.9 |
| **$F_2$** | **$F_2$SD** | Waste | 11.0 | 4.0 | 3.8 |
| **$F_3$** | **$F_3$SD** | Compost | 16.5 | 6.1 | 5.7 |
| **$F_4$** | **$F_4$SD** | (FWC) | 22.0 | 8.1 | 7.6 |
| **CF** | - | Chemical Fertilizer | 6.1 ** | 9.1 | 7.1 |
| **NF** | - | No Fertilizer | 0 | 0 | 0 |

* Uniform application of fertilizer. SSC and FWC were applied as basal dressing. **CF was applied 5.3 g N as basal ($N:P_2O_5:K_2O$=12:18:14) for growth survey, and 0.8 g N as top dressing ($N:P_2O_5:K_2O$=14:0:14) for yield survey in 2017.

**Soil and pots preparation**

The process of soil and pots preparation is the same as explained in chapter second (refer to page 13).

**Application of compost and chemical fertilizer**

Two types of compost (SSC and FWC) with different levels of N were applied uniformly and at one side (side dressing) of each treatment pot one day before transplanting as basal dressing. For the side dressing application method, composts were mixed with 1/6$^{th}$ part of the soil and added in a line, at the depth of 20 cm to the one side of the pot (7-8 cm aside from rice seedlings) at the basal. For the uniform application method, composts were mixed uniformly with all soil of one pot at the basal (Fig. 3.1). The amount of compost was depend to the percentage of total nitrogen content of each compost and its level. Therefore, the same weight of compost applied to the pot, the same weight of soil was removed from the pot.

CF treatment was applied as basal dressing and top dressing. Phosphorus ($P_2O_5$) and potassium ($K_2O$) at the rate of 7.92 g and 6.16 g per pot, respectively plus 5.28 g N per pot were applied uniformly as basal dressing for growth survey in 2016 and 2017, whose component was 12:18:14% of N:$P_2O_5$:$K_2O$. In addition, 0.77 g N per pot chemical fertilizer (N:$P_2O_5$:$K_2O$ = 14:0:14) was applied (1$^{st}$ July) as top dressing for yield survey in 2017. Basal dressing fertilizer of CF was uniformly mixed with soil of each treatment pot and composts fertilizer (SSC or FWC) was mixed with soil of each treatment pot either one side or uniformly, one day before transplanting.

**Variety Used**

The variety used was the same as explained in chapter second (refer to page 13 and 14).

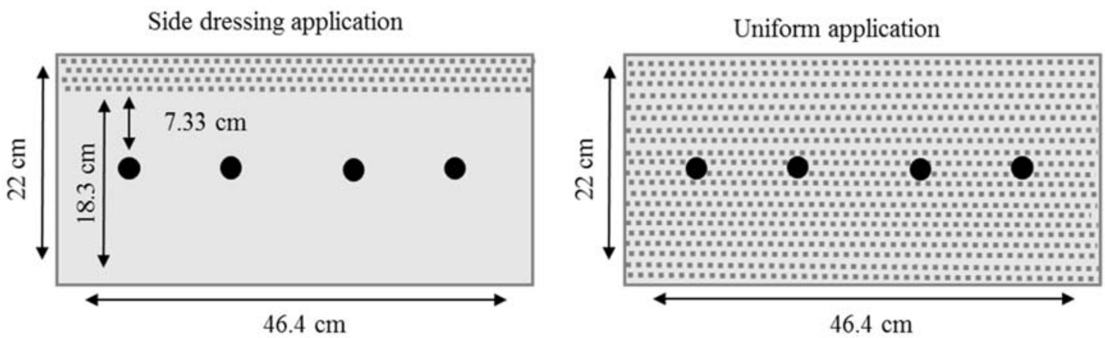
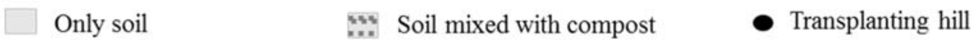



**Fig. 3.1 Diagram of application methods (Side dressing and uniform application).**



**Sowing and seed rate**

The rice cultivar "Koshihikari" seeds were soaked in water for 3 days at 30 °C temperature. Pregerminated seeds at rate of 150 g were sown in the nursery boxes (58cm × 28cm × 3cm) which were filled with sterilized soil on 1st and 22nd April 2016 (first and second repetition in 2016, respectively) and 1st April 2017 (Table 3.3). The nursery boxes were located in the greenhouse under controlled temperature condition until four-leaf stage.

**Transplanting**

Seedlings were separated based on their leaf age and the seedling at four-leaf stage were selected and transplanted into the pots. The transplanting dates of first and second repetitions in 2016 were on April 29th and May 13th, respectively and the transplanting dates in 2017 was April 29th (Table 3.3).

**Sampling**

The plants of two inner hills in each pot were sampled separately, soil and roots of each sample were separated using water pressure. The whole plant of each hill was divided into three parts (leaf blade, leaf sheath and root), for determination of their dry matter production. The sampling dates of first and second repetitions in 2016 were June 23rd and July 7th, respectively and there was no sampling for 2017. Table 3.3 indicates the sowing, transplanting and sampling dates, and accumulated daily temperature for 49 days from transplanting in 2016 and 2017.

**Table 3.3 Days of sowing, transplanting and sampling.**

| Year | Seasonal repetition | Sowing | Transplanting | Sampling | ADT** (°C days) |
|---|---|---|---|---|---|
| 2016 | First repetition* | 01-April | 29-April | 23-June | 1007.1 |
| | Second repetition | 22-April | 13-May | 07-July | 1084.0 |
| 2017 | First repetition* | 01-April | 29-April | *** | - |

* Popular transplanting date in Mie prefecture, Japan. ** Accumulated Daily Temperature for 49 days from transplanting. *** Harvesting.

The process for spacing, irrigation management, inter-culture and harvesting were the same as explained in chapter second (refer to page 14-15).

**Observations recorded**

In order to secure the effects of different treatments, the plant growth parameters (leaf emergence pattern, plant length, tiller numbers, soil pH, soil-plant analysis development value, heading and maturity date), dry matter production (dry weight of leaf blade, leaf sheath, root, top and T-R ratio) and yield components (top air-dry weight, weight of winnowed rough rice, straw weight, number of productive panicle, average number of spikelet per panicle, percentage of ripened grains, 1000-winnowed rough rice weight, culm length, panicle length, internodes length, maximum tiller number per hill, number of grain per panicle, percentage of productive culms and etc.) were recorded during the course of current pot experimentation.

**Plant growth parameters**

The two inner plants were measured for plant growth parameters (leaf emergence pattern, plant length and tiller numbers), avoiding the outer two plants for edge effects. Leaf emergence pattern, plant length and tiller numbers were recorded each week starting at 13 days after transplanting in 2016 and 2017.

The growth data were collected from the central two hills in each pot. The side hills' plants in each pot were used as border plants. The data of leaf emergence pattern and plant length in cm where recorded until sampling (first repetition 23 June and second repetition 7 July) in 2016 and until the appearance of flag leaf in 2017. The tiller numbers including maximum tiller number and productive tillers were counted until sampling in 2016 (Table 3.3) and until heading stage of each treatment in 2017 (Table 3.7).

**Soil pH**

Soil pH was determined for 6 weeks by digital pH meter (PRN-41, FUJIWARA) started from two WAT in 2016 and one WAT in 2017. The soil pH from 5-10 cm depth of two points in each pot was determined. The pH of two points was averaged to get per pot pH value.

**Dry matter production measurements**

Dry weight of samples of each hill were determined separately after sampling of each repetition in 2016. The procedure for sampling and data measurements are the same as explained in chapter three (refer to pages 71-72).

**Soil plant analysis development (SPAD) value**

The SPAD value was measured in 2017, the information is the same as described in chapter second (refer to pages 16-17).

**Heading and maturity date**

After the emergence of flag leaf, number of heading per hill was counted every day at 11:00 o'clock. The date when 50 percent of total tiller numbers emerged, was recorded as heading stage. Observation of heading continued until full heading stage, when 80 percent of the total panicles emerged. 30 days after heading stage, the data of maturity was recorded every day until harvesting.

### Yield components measurements

The whole plants of two interior hills in each pot were harvested at ground level separately at their maturity stages and banded with tags. The harvested material of each hill was air dried in the greenhouse for 20-30 days, then the data of yield components were recorded by the process explained in first experiment (refer to chapter second, in pages 17-19).

### Statistical analysis

The data obtained from different observations were analyzed by the same way described in first experiment (refer to chapter second, pages 19).

## Results

### Crop weather relationship

The performance of the rice plant is highly influenced by prevailing weather conditions, therefore data of rainfall and temperature collected during the crop seasons. Fig. 3.2 shows the 10 days average temperature (°C) and the amount of rainfall (mm) during the experiments from April 1st to the end of September 2016 and 2017 in Tsu city, Mie Prefecture. In comparison to 30 years (1981-2010) data of temperature and rainfall it was assumed that the weather conditions during the experimental period was normal in both years.

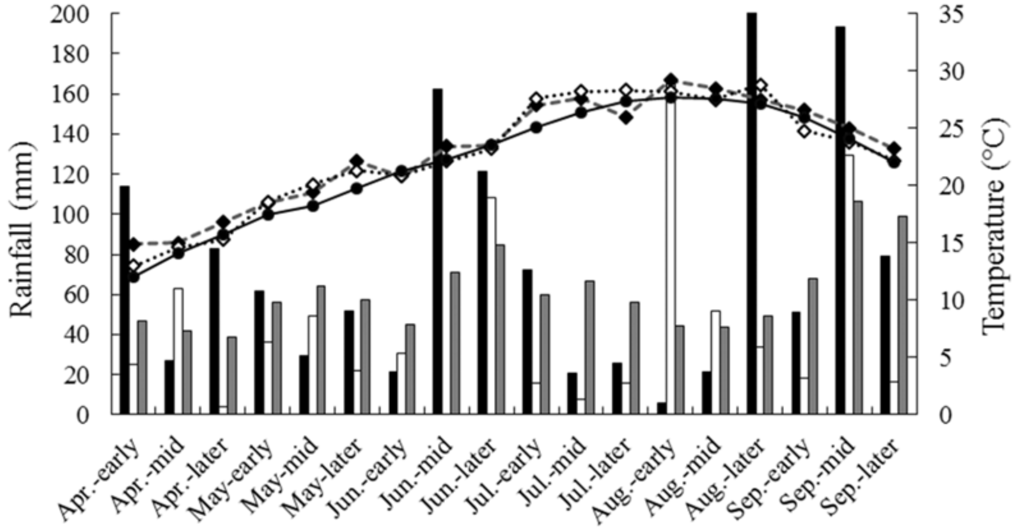



**Fig. 3.2 Measurements of temperature and rainfall during April-September in 2016 and 2017.**

Rainfall 2016 Rainfall 2017 Rainfall 1981-2010
Temperature 2016 Temperature 2017 Temperature 1981-2010

**Effects on plant growth characters:**

The result of this study show obviously effects of different application methods of SSC and FWC with their levels on plant growth parameters of rice. Leaf emergence pattern, plant length, tiller number, soil pH and SPAD value were differ by side dressing and uniform application method of SSC and FWC. The leaf emergence pattern, plant length and tiller numbers in SSC treatments were found higher than those of FWC treatments, and in side dressing application method than uniform application method in all growth stages of 2016 and 2017 (Table 3.4-3.6).

**Leaf emergence pattern (leaf age)**

The means of leaf emergence pattern of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1SD$, $S_2SD$, $S_3SD$ and $S_4SD$), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1SD$, $F_2SD$, $F_3SD$ and $F_4SD$), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of two repetitions in 2016 and one repetition in 2017 are demonstrated in Fig. 3.3 and Fig. 3.4, respectively and Table 3.4.

Fig.3.3 shows the effects of side and uniform application methods of SSC and FWC on leaf emergence pattern (leaf age) at the early stage of rice plant (from 2 WAT to 7 WAT) in 2016.

In first repetition of 2016 (transplanted on 29 April), the leaf emergence pattern of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their levels until 9$^{th}$ June, the high leaf emergence pattern was found in treatments $S_1$ and the minimum was recorded in treatments $S_4$. Treatment $S_4$ was depressed in comparison to treatment NF until 9$^{th}$ June (a1 in Fig. 3.3). However, the leaf emergence pattern of SSC treatments applied by side dressing method ($S_1SD$, $S_2SD$, $S_3SD$ and $S_4SD$) did not significantly differ among each other until 16th June. From 2nd June treatments $S_1SD$, $S_2SD$, $S_3SD$ and $S_4SD$ were higher than treatment NF but lower than control treatment CF (a3 in Fig. 3.3).

The leaf emergence pattern of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) was inhibited by increasing their levels throughout the plant life, on 16th June, the high leaf emergence pattern was found in treatment $F_1$ (10.5) and the minimum was registered with treatments $F_4$ (8.9). Treatment CF recorded higher (11.9) than all FWC treatments. All FWC treatments applied by uniform application method were even smaller than treatment NF until 16th June (paddy soil condition with no fertilizer) (a2 in Fig. 3.3). Though, the leaf emergence pattern of FWC treatments applied by side dressing method ($F_1SD$, $F_2SD$, $F_3SD$ and $F_4SD$) did not significantly differ among each other and NF treatment until 16th June but lower than control treatment CF (a4 in Fig. 3.3).

In second repetition of 2016 (transplanted on 13 May), leaf emergence pattern of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were not depressed in comparison to control treatment NF. From 16th June treatments $S_1$, $S_2$, $S_3$ and $S_4$ tended to be higher than NF treatment and approach to control treatment CF (a5 in Fig. 3.3). The leaf emergence pattern of SSC treatments applied by side dressing method ($S_1SD$, $S_2SD$, $S_3SD$ and $S_4SD$) had the same tendency as they had by uniform application method (a7 in Fig. 3.3).

The leaf emergence pattern of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) was decreased by increasing the N levels of compost (amount) until 23rd June. Treatment NF was higher than treatments $F_1$ until 16th June, $F_2$ until 23rd June and $F_3$ and $F_4$ until 30th June. Control treatment CF recorded higher (12.5) than all FWC treatments throughout the initial growth stage (a6 in Fig. 3.3). However, the leaf emergence pattern of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other and NF treatment until 30$^{th}$ June but all treatments were lower than control treatment CF (a8 in Fig. 3.3).

Fig. 3.4 shows the effects of side and uniform application methods of SSC and FWC on leaf emergence pattern (leaf age) during the rice plant growth (from 2 WAT to 12 WAT) in 2017.

In 2017, leaf emergence pattern of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were not depressed in comparison to treatment NF. But in comparison to control treatment CF, treatment $S_1$ was at par with CF and treatment $S_4$ was lower until 8$^{th}$ July. Though, on 22$^{nd}$ July, treatment $S_4$ recorded at par with treatment CF and the $S_1$ treatment was registered lower than CF. Treatment NF (no fertilizer) recorded the lower leaf emergence pattern than SSC treatments (a1 in Fig. 3.4). However, the leaf emergence pattern of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ among each other and NF but from 3$^{rd}$ June treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD were increased than treatment NF (a3 in Fig. 3.4).

The leaf emergence pattern of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) was depressed by increasing their levels until 24$^{th}$ June in comparison to treatment NF, afterward they were found at par with NF until 8$^{th}$ July, and from 8$^{th}$ July the leaf emergence pattern of $F_1$, $F_2$, $F_3$ and $F_4$ treatments were increased than NF. Treatment CF recorded higher than all FWC treatments applied by uniform method and NF (a2 in Fig. 3.4). However, the leaf emergence pattern of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other until 22$^{nd}$ July.

They were also at par with NF treatment until 8th July afterward treatments $F_1SD$, $F_2SD$, $F_3SD$ and $F_4SD$ increased than NF. All treatments were found lower than control treatment CF throughout the growth survey (a4 in Fig. 3.4).

From the results of two repetitions in 2016 and one repetition in 2017 (Fig. 3.3 and Fig. 3.4, and Table 3.4.), it was found that the basal application of FWC and SSC had inhibiting effects on the leaf emergence pattern at the early growth stage of rice plants, while the inhibition was reduced at the late stage. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effects of FWC was heavier than that of SSC. Uniform application of compost which is common in rice production, caused inhibition effects at the early growth stage of rice plants. Side dressing method was found better than the uniform application. This method reduced the inhibition effects at the early growth stage.

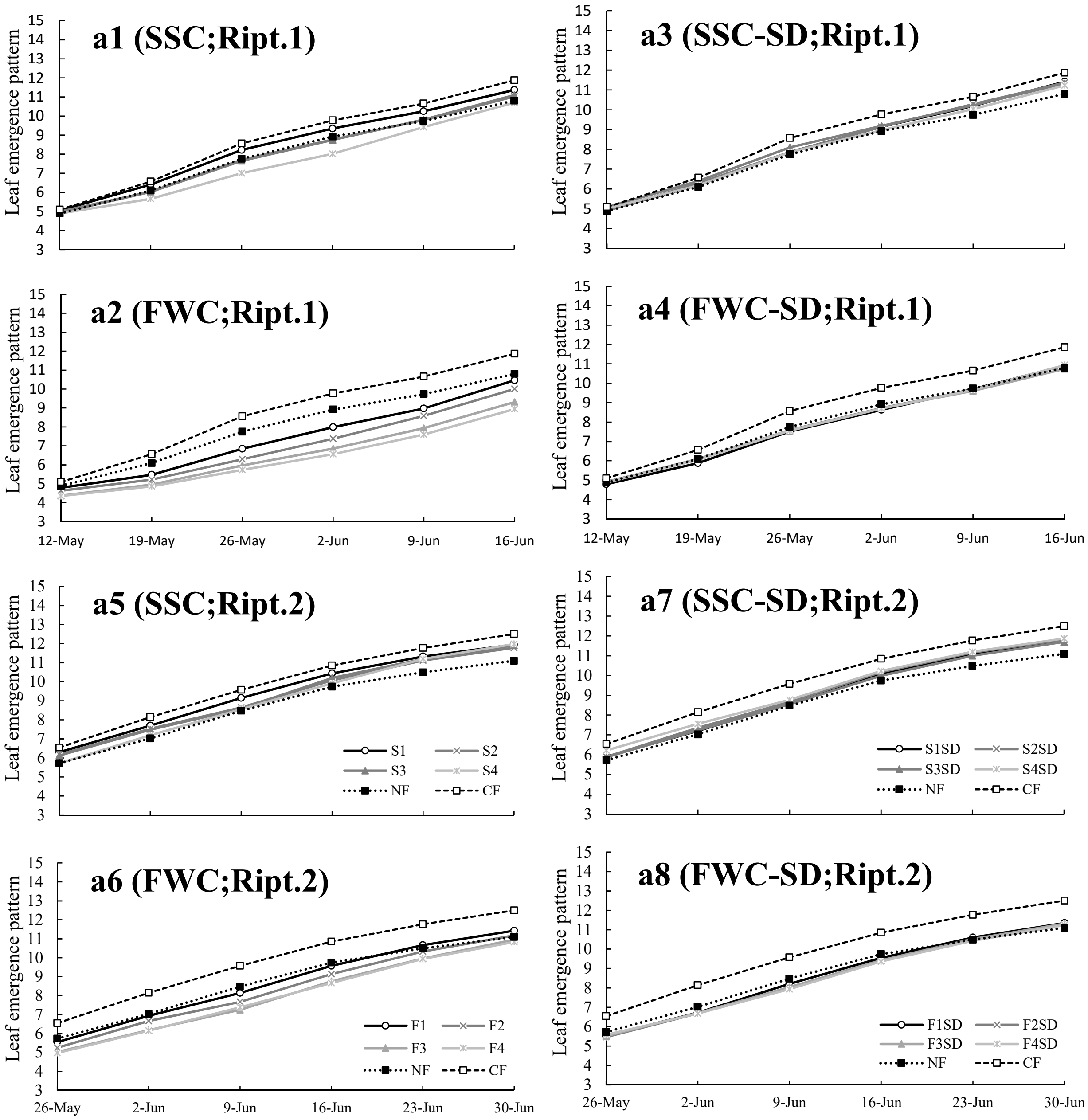



**Fig. 3.3 Effects of side and uniform application methods of SSC and FWC on leaf age (leaf emergence pattern) at the early stage of rice plant in 2016.**

a1-a4 show leaf emergence pattern (leaf age) in first repetition. a5-a8 show leaf emergence pattern (leaf age) in second repetition. Uniform application method indicated in a1, a2, a5 and a6. Side dressing method shown in a3, a4, a7 and a8. Data represent mean ± standard deviation (n = 3). Rept. means repetition. SD means side dressing.

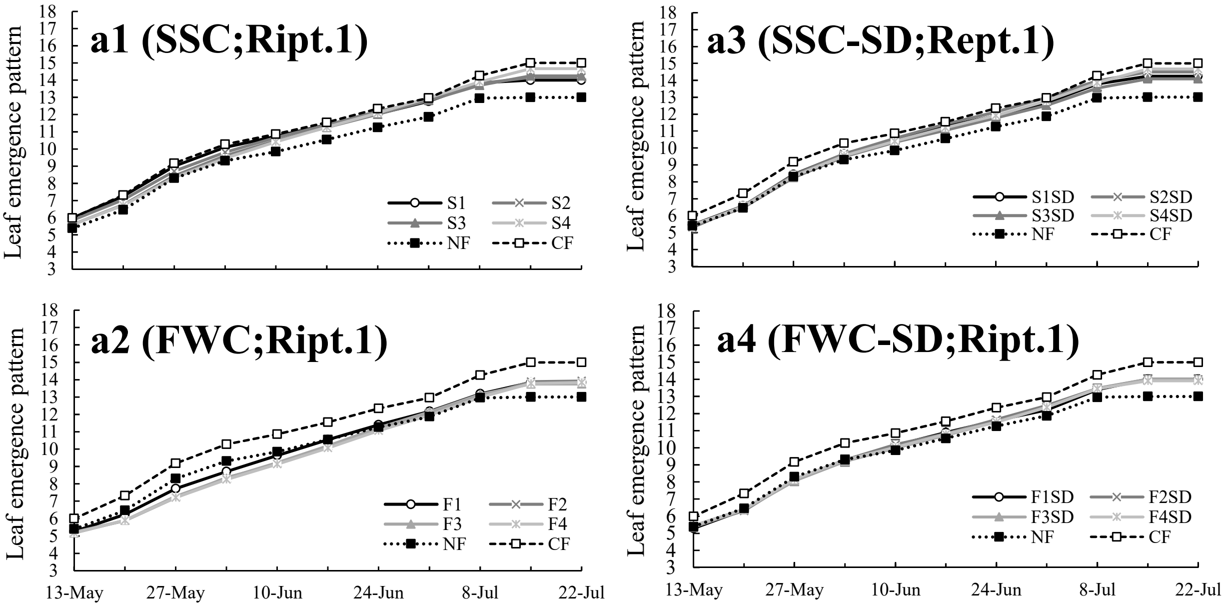



**Fig. 3.4 Effects of side and uniform application methods of SSC and FWC on leaf age (leaf emergence pattern) during the rice plant growth in 2017.**

Uniform application method indicated in a1 and a2. Side dressing method shown in a3 and a4. Data represent mean ± standard deviation (n = 3). Rept. means repetition. SD means side dressing.

**Table 3.4 Leaf emergence pattern (leaf age) in 2016 and 2017.**

| Years | | First repetition | | | | | | Second repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun |
| 2016 | S1 | 5.1 | 6.4 | 8.2 | 9.3 | 10.3 | 11.4 | 6.3 | 7.7 | 9.1 | 10.4 | 11.3 | 11.9 |
| | S2 | 5.0 | 6.0 | 7.7 | 8.8 | 9.8 | 11.0 | 6.2 | 7.5 | 8.6 | 10.1 | 11.1 | 11.8 |
| | S3 | 4.9 | 6.0 | 7.7 | 8.7 | 9.8 | 11.1 | 6.1 | 7.5 | 8.6 | 10.2 | 11.2 | 11.9 |
| | S4 | 4.9 | 5.7 | 7.0 | 8.0 | 9.4 | 10.7 | 5.7 | 7.2 | 8.6 | 9.9 | 11.2 | 12.0 |
| | F1 | 4.8 | 5.5 | 6.9 | 8.0 | 9.0 | 10.5 | 5.5 | 6.9 | 8.1 | 9.6 | 10.7 | 11.4 |
| | F2 | 4.6 | 5.2 | 6.3 | 7.4 | 8.6 | 10.0 | 5.2 | 6.7 | 7.7 | 9.1 | 10.3 | 11.2 |
| | F3 | 4.4 | 5.0 | 6.0 | 6.9 | 7.9 | 9.3 | 5.0 | 6.2 | 7.2 | 8.8 | 10.0 | 11.0 |
| | F4 | 4.4 | 4.9 | 5.7 | 6.6 | 7.6 | 8.9 | 5.0 | 6.1 | 7.4 | 8.7 | 9.9 | 10.8 |
| | S1SD | 4.9 | 6.2 | 7.9 | 9.1 | 10.2 | 11.4 | 5.9 | 7.2 | 8.6 | 10.1 | 11.1 | 11.8 |
| | S2SD | 4.9 | 6.3 | 7.9 | 9.1 | 10.3 | 11.4 | 5.9 | 7.4 | 8.7 | 10.2 | 11.2 | 11.8 |
| | S3SD | 5.1 | 6.4 | 8.1 | 9.2 | 10.2 | 11.3 | 5.9 | 7.2 | 8.6 | 10.0 | 11.0 | 11.7 |
| | S4SD | 5.0 | 6.2 | 7.9 | 9.0 | 10.0 | 11.2 | 6.2 | 7.6 | 8.8 | 10.2 | 11.2 | 11.9 |
| | F1SD | 4.8 | 5.9 | 7.5 | 8.6 | 9.7 | 10.9 | 5.5 | 6.7 | 8.2 | 9.6 | 10.6 | 11.3 |
| | F2SD | 4.9 | 6.1 | 7.6 | 8.7 | 9.7 | 10.9 | 5.5 | 6.7 | 8.0 | 9.4 | 10.5 | 11.3 |
| | F3SD | 4.9 | 6.1 | 7.6 | 8.7 | 9.6 | 10.7 | 5.5 | 6.7 | 8.0 | 9.4 | 10.5 | 11.3 |
| | F4SD | 4.9 | 6.1 | 7.6 | 8.7 | 9.7 | 10.9 | 5.6 | 6.7 | 7.9 | 9.4 | 10.4 | 11.2 |
| | NF | 4.9 | 6.1 | 7.8 | 8.9 | 9.7 | 10.8 | 5.7 | 7.0 | 8.5 | 9.7 | 10.5 | 11.1 |
| | CF | 5.1 | 6.6 | 8.6 | 9.8 | 10.7 | 11.9 | 6.5 | 8.1 | 9.6 | 10.9 | 11.8 | 12.5 |
| | | First repetition | | | | | | | | | | | |
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul | |
| 2017 | S1 | 6.0 | 7.2 | 9.0 | 10.1 | 10.7 | 11.4 | 12.0 | 12.8 | 13.9 | 14.0 | 14.0 | |
| | S2 | 5.9 | 7.0 | 8.7 | 9.8 | 10.7 | 11.4 | 12.2 | 12.8 | 13.8 | 14.2 | 14.2 | |
| | S3 | 5.6 | 6.8 | 8.4 | 9.6 | 10.5 | 11.3 | 12.0 | 12.8 | 13.7 | 14.3 | 14.3 | |
| | S4 | 5.6 | 6.7 | 8.3 | 9.5 | 10.4 | 11.3 | 12.1 | 13.0 | 13.9 | 14.7 | 14.7 | |
| | F1 | 5.3 | 6.2 | 7.7 | 8.7 | 9.6 | 10.5 | 11.4 | 12.2 | 13.2 | 13.8 | 13.8 | |
| | F2 | 5.2 | 5.9 | 7.2 | 8.4 | 9.1 | 10.2 | 11.1 | 12.1 | 13.0 | 13.9 | 13.9 | |
| | F3 | 5.2 | 5.9 | 7.3 | 8.3 | 9.2 | 10.2 | 11.2 | 12.1 | 13.2 | 13.8 | 13.8 | |
| | F4 | 5.2 | 5.9 | 7.2 | 8.3 | 9.1 | 10.1 | 11.1 | 12.0 | 13.0 | 13.8 | 13.8 | |
| | S1SD | 5.5 | 6.6 | 8.4 | 9.6 | 10.5 | 11.3 | 11.9 | 12.7 | 13.8 | 14.3 | 14.3 | |
| | S2SD | 5.3 | 6.6 | 8.4 | 9.7 | 10.6 | 11.4 | 12.1 | 13.0 | 14.0 | 14.5 | 14.5 | |
| | S3SD | 5.4 | 6.5 | 8.2 | 9.5 | 10.3 | 11.1 | 11.8 | 12.5 | 13.5 | 14.1 | 14.1 | |
| | S4SD | 5.4 | 6.5 | 8.3 | 9.5 | 10.4 | 11.2 | 11.9 | 12.8 | 13.9 | 14.7 | 14.7 | |
| | F1SD | 5.3 | 6.4 | 8.1 | 9.3 | 10.2 | 10.9 | 11.6 | 12.2 | 13.4 | 14.0 | 14.0 | |
| | F2SD | 5.4 | 6.3 | 8.1 | 9.3 | 10.2 | 10.8 | 11.6 | 12.5 | 13.5 | 14.0 | 14.0 | |
| | F3SD | 5.4 | 6.4 | 8.1 | 9.2 | 10.0 | 10.7 | 11.5 | 12.4 | 13.4 | 14.0 | 14.0 | |
| | F4SD | 5.5 | 6.4 | 8.2 | 9.3 | 10.0 | 10.8 | 11.5 | 12.4 | 13.5 | 13.9 | 13.9 | |
| | NF | 5.4 | 6.5 | 8.3 | 9.3 | 9.9 | 10.6 | 11.3 | 11.9 | 13.0 | 13.0 | 13.0 | |
| | CF | 6.0 | 7.3 | 9.2 | 10.3 | 10.9 | 11.5 | 12.3 | 13.0 | 14.3 | 15.0 | 15.0 | |

**Plant length (cm)**

The means plant length (cm) of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of two repetitions in 2016 and one repetition in 2017 are demonstrated in Fig. 3.5 and Fig. 3.6, respectively and Table 3.5.

Fig.3.5 shows the effects of side and uniform application methods of SSC and FWC on plant length (cm) at the early growth stage of rice plant (from 2 WAT to 7 WAT) in 2016.

In first repetition of 2016 (transplanted on 29 April), the plant length of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their levels during the initial plant growth, the high plant length was found in treatments $S_1$ and the minimum was recorded in treatments $S_4$. Treatments $S_4$, $S_3$ and $S_2$ were depressed in comparison to treatment NF until 9$^{th}$ June. Control treatment CF recorded higher plant length than all SSC treatments (b1 in Fig. 3.5). However, the plant length of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ among each other until 16$^{th}$ June. From 2$^{nd}$ June treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD were tended to be higher than treatment NF but lower than control treatment CF (b3 in Fig. 3.5).

The plan length of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) were inhibited by increasing their levels throughout the initial plant growth, on 16$^{th}$ June, the high plant length was found in treatment $F_1$ (48.3 cm) and the minimum was registered with treatments $F_4$ (32.7 cm). Treatment CF recorded significantly higher plant length (71.0 cm) than all FWC treatments. All FWC treatments applied by uniform application method were even smaller than treatment NF treatment (paddy soil condition with no fertilizer) at the early growth stage. Only treatment $S_1$ was at par with treatment NF on $16^{th}$ June (b2 in Fig. 3.5). Though, the plant length of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other and NF treatment until $16^{th}$ June but they were lower than control treatment CF (b4 in Fig. 3.5).

In second repetition of 2016 (transplanted on 13 May), plant length of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were not depressed in comparison to control treatment NF. From $9^{th}$ June treatments $S_1$, $S_2$, $S_3$ and $S_4$ tended to be higher than NF treatment and approach to control treatment CF (b5 in Fig. 3.5). The plant length of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not differ among each other and they had the same tendency of plant length as the treatments of uniform application method had (b7 in Fig. 3.5).

The plant length of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) was decreased by increasing the N levels of compost (amount) until $30^{rd}$ June. From $23^{rd}$ June, treatments $F_1$, $F_2$, $F_3$ and $F_4$ tended to increase than NF treatment. Control treatment CF recorded higher than all FWC treatments and NF throughout the initial growth stage (b6 in Fig. 3.5). However, the plant length of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other and NF treatment but from $23^{rd}$ June, treatments $F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD tended to increase plant length than NF treatment. Control treatment CF recorded significantly higher plant length than all other treatments (b8 in Fig. 3.5).

Fig. 3.6 shows the effects of side and uniform application methods of SSC and FWC on plant length (cm) during the rice plant growth (from 2 WAT to 12 WAT) in 2017.

In 2017, plant length of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were not depressed after 3rd June in comparison to treatment NF. From 13th May to 17th June the plant length decreased by increasing the N levels (compost amount) but from 17th June it has conversely changed and the plant length increased by increasing the N levels. Control treatment CF was higher than all other treatments throughout the plant growth except for treatments $S_3$ and $S_4$ that from 1st July were at par with CF. Treatment NF (no fertilizer) recorded the lower plant length than SSC treatments (b1 in Fig. 3.6). However, plant length of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ with treatment NF until 3rd June and among each other until 1st July. From 1st July treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD were increased by increasing the N levels of compost. At 12 WAT (22nd July), maximum plant length was recorded in $S_4$SD and $S_3$SD which were at pare with CF and the minimum was counted in treatment NF which was followed by treatment $S_1$SD (b3 in Fig. 3.6).

The plant length of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) were depressed by increasing their levels until 17th June in comparison to treatment NF, afterward they were increased. From 8th July, treatments $F_4$, $F_3$ and $F_2$ approached to the control treatment CF. Treatment CF recorded higher plant length than all FWC treatments applied by uniform method (b2 in Fig. 3.6). However, the plant length of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other until 24th June. They were also at par with NF treatment until 17th June afterward plant length of treatments $F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD increased than NF and tended to approach to the CF treatment. All treatments were found lower than control treatment CF throughout the growth survey except treatments $F_4SD$ and $F_3SD$ which were at par with CF from 15th July (b4 in Fig. 3.6).

From the results of two repetitions in 2016 and one repetition in 2017 (Fig. 3.5 and Fig. 3.6, and Table 3.5.), it was found that the basal application of FWC and SSC had inhibiting effects on the plant length at the early growth stage of rice plants, while the inhibition was reduced at the late stage. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effects of FWC was heavier than that of SSC. Uniform application of compost which is common in rice production, caused inhibition effects at the early growth stage of rice plants. Side dressing method was found better than the uniform application. This method reduced the inhibition effects at the early growth stage.

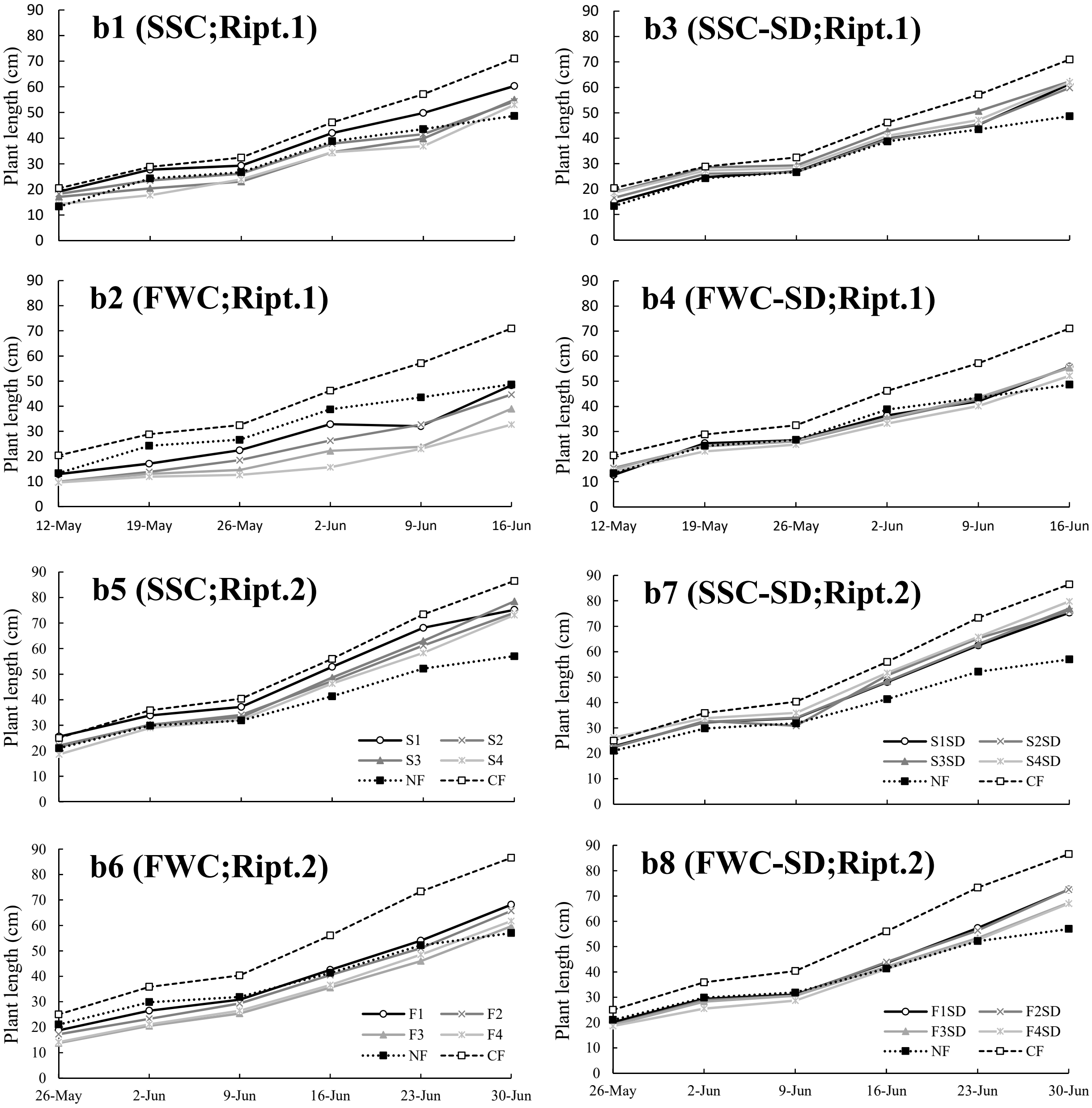



**Fig. 3.5 Effects of side and uniform application methods of SSC and FWC on plant length at the early stage of rice plant in 2016.**

b1-b4 show plant length in first repetition. b5-b8 show plant length in second repetition. Uniform application method indicated in b1, b2, b5 and b6. Side dressing method shown in b3, b4, b7 and b8. Data represent mean ± standard deviation (n = 3). Rept. means repetition. SD means side dressing.

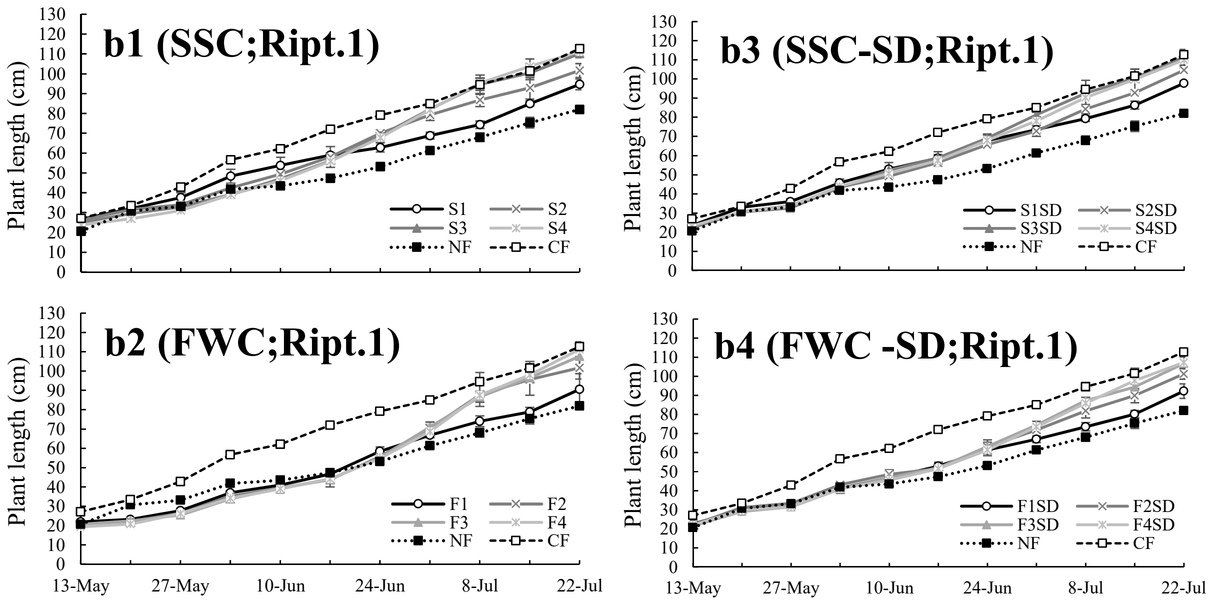



**Fig. 3.6 Effects of side and uniform application methods of SSC and FWC on plant length during the rice plant growth in 2017.**

Uniform application method indicated in b1 and b2. Side dressing method shown in b3 and b4. Data represent mean ± standard deviation (n = 3). Rept. means repetition.

**Table 3.5 Plant length (cm) in 2016 and 2017.**

| Years | | First repetition | | | | | | Second repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun |
| 2016 | S1 | 19.1 | 27.7 | 29.3 | 42.0 | 49.8 | 60.3 | 25.5 | 33.8 | 37.2 | 52.8 | 68.2 | 75.2 |
| | S2 | 18.3 | 23.5 | 26.2 | 37.8 | 41.5 | 54.3 | 22.0 | 30.2 | 34.0 | 47.3 | 61.2 | 74.0 |
| | S3 | 17.1 | 20.4 | 23.0 | 34.5 | 39.8 | 55.0 | 21.5 | 30.2 | 33.2 | 48.7 | 63.0 | 78.5 |
| | S4 | 14.3 | 17.7 | 23.9 | 34.5 | 36.8 | 53.0 | 18.6 | 29.0 | 32.2 | 46.3 | 58.3 | 73.2 |
| | F1 | 13.0 | 17.1 | 22.4 | 32.8 | 32.1 | 48.3 | 18.8 | 26.5 | 30.8 | 42.5 | 54.0 | 68.2 |
| | F2 | 10.0 | 13.8 | 18.5 | 26.3 | 32.7 | 44.7 | 17.2 | 23.3 | 29.3 | 40.5 | 51.0 | 65.7 |
| | F3 | 10.0 | 13.0 | 14.6 | 22.2 | 23.8 | 39.0 | 13.8 | 20.5 | 25.4 | 35.5 | 46.0 | 59.7 |
| | F4 | 9.6 | 11.9 | 12.7 | 15.7 | 23.0 | 32.7 | 14.1 | 21.2 | 26.5 | 36.5 | 48.5 | 61.7 |
| | S1SD | 14.7 | 24.7 | 26.9 | 39.8 | 45.3 | 61.3 | 22.8 | 32.2 | 33.8 | 48.0 | 62.5 | 75.3 |
| | S2SD | 16.6 | 26.0 | 26.7 | 39.6 | 45.5 | 59.8 | 22.4 | 32.7 | 30.8 | 50.7 | 65.2 | 76.0 |
| | S3SD | 18.8 | 28.5 | 29.3 | 42.8 | 50.7 | 62.3 | 22.5 | 32.3 | 34.0 | 48.3 | 63.0 | 77.0 |
| | S4SD | 18.5 | 27.3 | 28.3 | 40.9 | 47.2 | 62.0 | 26.2 | 33.8 | 36.0 | 51.7 | 65.8 | 79.8 |
| | F1SD | 12.7 | 25.3 | 26.5 | 36.4 | 42.0 | 55.8 | 20.1 | 29.3 | 31.0 | 43.5 | 57.3 | 72.5 |
| | F2SD | 15.4 | 24.1 | 26.1 | 35.0 | 42.8 | 55.7 | 19.2 | 28.8 | 30.7 | 43.8 | 56.3 | 72.5 |
| | F3SD | 15.1 | 24.4 | 26.3 | 35.3 | 43.5 | 55.3 | 19.0 | 28.2 | 30.5 | 42.0 | 53.3 | 67.3 |
| | F4SD | 14.2 | 22.1 | 24.8 | 33.2 | 40.2 | 52.2 | 18.6 | 25.5 | 28.7 | 41.2 | 52.7 | 67.0 |
| | NF | 13.3 | 24.3 | 26.7 | 38.8 | 43.5 | 48.7 | 21.0 | 29.8 | 31.8 | 41.3 | 52.2 | 57.0 |
| | CF | 20.4 | 28.8 | 32.4 | 46.2 | 57.2 | 71.0 | 25.0 | 35.8 | 40.3 | 56.0 | 73.3 | 86.5 |
| | | First repetition | | | | | | | | | | | |
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul | |
| 2017 | S1 | 26.5 | 32.1 | 37.5 | 48.3 | 53.8 | 59.0 | 62.8 | 68.8 | 74.3 | 85.0 | 94.7 | |
| | S2 | 26.2 | 31.5 | 34.0 | 42.5 | 49.3 | 58.2 | 70.0 | 79.3 | 86.8 | 93.0 | 101.7 | |
| | S3 | 25.0 | 29.6 | 32.8 | 39.2 | 47.0 | 56.2 | 68.8 | 82.2 | 94.7 | 100.5 | 110.2 | |
| | S4 | 23.8 | 26.8 | 31.0 | 39.0 | 46.2 | 55.8 | 67.8 | 81.8 | 95.3 | 103.8 | 111.2 | |
| | F1 | 21.9 | 23.2 | 27.8 | 37.0 | 41.0 | 46.7 | 58.5 | 66.8 | 74.0 | 78.8 | 90.5 | |
| | F2 | 20.5 | 22.2 | 26.3 | 35.2 | 39.4 | 43.8 | 55.7 | 70.3 | 87.7 | 95.7 | 101.7 | |
| | F3 | 20.7 | 22.5 | 25.5 | 33.8 | 39.3 | 44.0 | 55.0 | 71.0 | 86.7 | 96.5 | 107.7 | |
| | F4 | 19.4 | 20.8 | 26.2 | 34.2 | 39.0 | 44.2 | 54.8 | 68.7 | 87.5 | 98.0 | 111.3 | |
| | S1SD | 23.5 | 33.0 | 36.0 | 45.7 | 53.0 | 58.7 | 67.8 | 73.5 | 79.3 | 86.3 | 97.8 | |
| | S2SD | 22.2 | 30.8 | 33.9 | 43.5 | 49.3 | 56.3 | 65.7 | 72.8 | 84.3 | 92.8 | 104.7 | |
| | S3SD | 22.3 | 30.5 | 32.6 | 43.2 | 52.3 | 58.8 | 69.0 | 81.3 | 92.5 | 100.7 | 111.3 | |
| | S4SD | 23.2 | 30.6 | 33.7 | 44.0 | 50.7 | 57.5 | 68.0 | 78.0 | 90.3 | 99.8 | 110.0 | |
| | F1SD | 22.5 | 30.1 | 31.6 | 41.2 | 46.8 | 52.8 | 61.3 | 67.0 | 73.5 | 80.2 | 92.2 | |
| | F2SD | 22.1 | 31.2 | 33.4 | 43.2 | 48.7 | 51.7 | 63.0 | 71.8 | 81.8 | 89.8 | 101.2 | |
| | F3SD | 21.5 | 29.2 | 31.5 | 40.8 | 46.8 | 52.0 | 63.2 | 74.3 | 87.2 | 94.3 | 106.7 | |
| | F4SD | 22.1 | 29.8 | 31.7 | 41.2 | 45.5 | 51.5 | 61.3 | 73.5 | 85.8 | 97.7 | 107.2 | |
| | NF | 20.6 | 30.7 | 33.2 | 41.8 | 43.5 | 47.3 | 53.2 | 61.3 | 68.0 | 75.3 | 82.0 | |
| | CF | 27.1 | 33.4 | 42.8 | 56.7 | 62.2 | 72.0 | 79.2 | 85.0 | 94.5 | 101.5 | 112.7 | |

**Tiller number**

The means of tiller number per hill of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of two repetitions in 2016 and one repetition in 2017 are demonstrated in Fig. 3.7 and Fig. 3.8, respectively and Table 3.6.

Fig.3.7 shows the effects of side and uniform application methods of SSC and FWC on tiller number at the early growth stage of rice plant (from 2 WAT to 7 WAT) in 2016.

In first repetition of 2016 (transplanted on 29 April), the tiller number of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) decreased by increasing their levels during the initial plant growth, the high tiller number was found in treatments $S_1$ and the minimum was recorded in treatments $S_4$. Treatments $S_2$, $S_3$ and $S_4$ were depressed in comparison to treatment NF until 9$^{th}$ June. Control treatment CF recorded higher tiller number than all SSC treatments throughout the plant growth (c1 in Fig. 3.7). However, the tiller number of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ among each other until 16$^{th}$ June. From 2$^{nd}$ June number of tillers of treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD were tended to be higher than treatment NF but significantly lower than control treatment CF (c3 in Fig. 3.7).

The mean tiller number of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) were decreased by increasing their N level throughout the initial plant growth. Among FWC treatments, the maximum was found in treatment $F_1$ and the minimum was recorded in treatment $F_4$. The tiller number of $F_1$, $F_2$, $F_3$ and $F_4$ treatments were significantly lower than control treatment CF, they were even lower than treatment NF (no fertilizer) until 7 WAT (16$^{th}$ June) (c2 in Fig. 3.7). Though, the tiller number of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other and NF until 16$^{th}$ June but they were significantly lower than control treatment CF (c4 in Fig. 3.7).

In second repetition of 2016 (transplanted on 13 May), tiller number of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were decreased by increasing the N levels of compost. From 9$^{th}$ June, number of tillers of treatments $S_1$, $S_2$, $S_3$ and $S_4$ increased than NF treatment. At 7 WAT (30$^{th}$ June) they were at par with each other, higher than NF treatment but significantly lower than control treatment CF (c5 in Fig. 3.7). The tiller number of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not differ with treatment NF until 9$^{th}$ June and among each other until 30$^{th}$ June. From 9$^{th}$ June tiller number of treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD increased significantly than the NF (c7 in Fig. 3.7).

The tiller number of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) was decreased by increasing the N levels of compost (amount) until 30$^{rd}$ June. Until 16$^{th}$ June, treatments $F_1$, $F_2$, $F_3$ and $F_4$ were lower than treatment NF, afterward, treatments $F_1$, and $F_2$ tended to increase than NF. Control treatment CF recorded higher than all FWC treatments and NF throughout the initial growth stage (c6 in Fig. 3.7). However, the tiller number of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other and NF treatment but from 23$^{rd}$ June, treatments $F_1$SD, $F_2$SD and $F_3$SD tended to increase tiller number than NF treatment. Control treatment CF recorded significantly higher number of tiller than all other treatments (c8 in Fig. 3.7).

Fig. 3.8 shows the effects of side and uniform application methods of SSC and FWC on tiller number per hill during the rice plant growth (from 2 WAT to 12 WAT) in 2017.

In 2017, mean tiller number of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$) were not depressed after 3rd June in comparison to treatment NF. From 13th May to 24th June the tiller number were decreased by increasing the N levels (compost amount) but from 24th June it has conversely changed and the tiller number of treatments $S_1$, $S_2$, $S_3$ and $S_4$ increased by increasing the N levels. Control treatment CF was higher than all other treatments throughout the plant growth except for treatments $S_3$ and $S_4$ were approached to CF at late stage (22nd July). Treatment NF (no fertilizer) recorded the lower tiller number than SSC treatments (c1 in Fig. 3.8). However, tiller number of SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ with treatment NF until 27th May and among each other until 17th June. From 17th June treatments $S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD were increased by increasing the N levels of compost. At 12 WAT (22nd July), maximum number of tiller was recorded in treatments $S_4$SD and $S_3$SD which were at pare with CF and the minimum was counted in treatment NF which was followed by treatment $S_1$SD (b3 in Fig. 3.6).

The tiller number of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) were depressed by increasing their levels until 24th June in comparison to treatment NF, afterward they were increased. From 8th July, treatments $F_4$, $F_3$ and $F_2$ were at par with each other. Treatment CF recorded higher tiller number than all FWC treatments applied by uniform method and treatment NF (c2 in Fig. 3.8). However, the tiller number of FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ among each other until 22nd July. They were also at par with NF treatment until 10th June afterward number of tillers of treatments $F_1SD$, $F_2SD$, $F_3SD$ and $F_4SD$ increased than NF. Tiller number of all treatments were found lower than control treatment CF throughout the growth survey (c4 in Fig. 3.8). It indicates in c2 and c4 of fig. 3.8 that FWC treatments were inhibited by uniform application, but the inhibition reduced by side dressing. From 2 to 7 WAT tiller number of FWC treatments applied uniformly were lower than NF (no fertilizer level of soil) however, with side dressing the tiller number of FWC treatments were same to NF until 5 WAT and increased afterward.

From the results of two repetitions in 2016 and one repetition in 2017 (Fig. 3.5 and Fig. 3.6, and Table 3.5.), it was found that the basal application of FWC and SSC had inhibiting effects on the tiller number at the early growth stage of rice plants, while the inhibition was reduced at the late stage. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effects of FWC was heavier than that of SSC. Uniform application of compost which is common in rice production, caused inhibition effects at the early growth stage of rice plants. Side dressing method was found better than the uniform application. This method reduced the inhibition effects at the early growth stage.

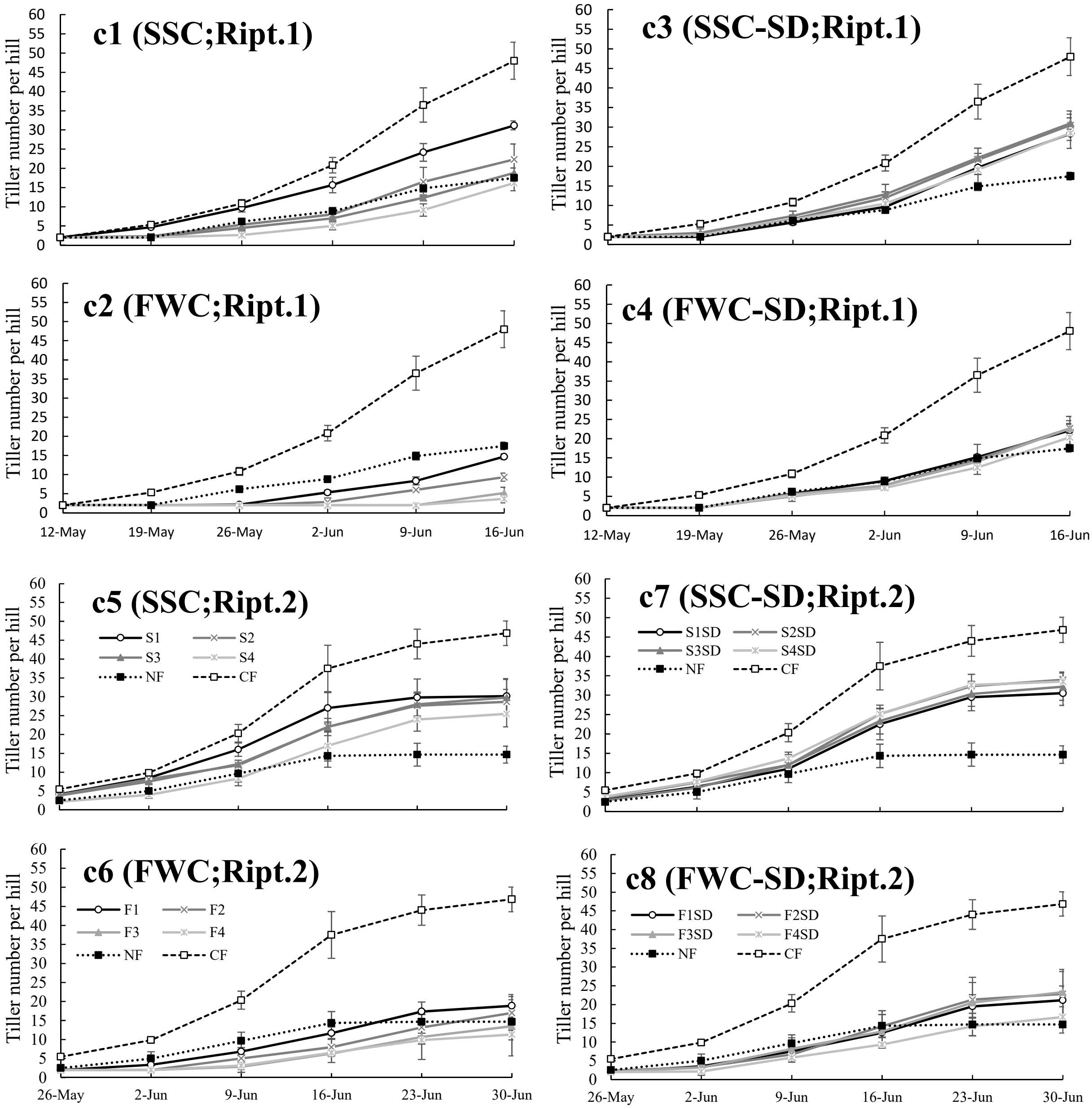



**Fig. 3.7 Effects of side and uniform application methods of SSC and FWC on tiller number at the early stage of rice plant in 2016.**

c1-c4 show tiller number per hill in first repetition. c5-c8 show tiller number per hill in second repetition. Uniform application method indicated in c1, c2, c5 and c6. Side dressing method shown in c3, c4, c7 and c8. Data represent mean ± standard deviation (n = 3). Rept. means repetition. SD means side dressing.

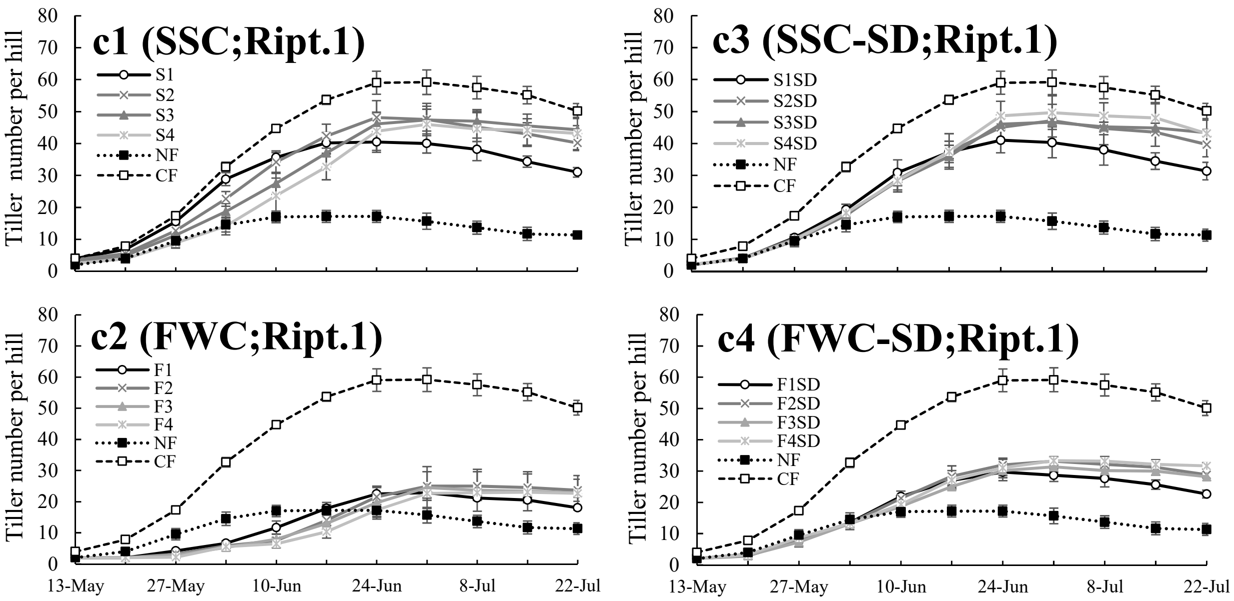



**Fig. 3.8 Effects of side and uniform application methods of SSC and FWC on tiller number during the rice plant growth in 2017.**

Uniform application method indicated in c1 and c2. Side dressing method shown in c3 and c4. Data represent mean ± standard deviation (n = 3). Rept. means repetition. SD means side dressing.

**Table 3.6 Tiller numbers per hill in 2016 and 2017.**

| Years | Treatment | First repetition | | | | | | Second repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun | 30-Jun |
| 2016 | **S1** | 2.0 | 4.7 | 9.7 | 15.7 | 24.2 | 31.2 | 4.2 | 8.5 | 16.0 | 27.0 | 29.8 | 30.2 |
| | **S2** | 2.0 | 2.3 | 5.3 | 8.0 | 16.5 | 22.3 | 4.0 | 8.2 | 11.8 | 22.0 | 27.7 | 28.7 |
| | **S3** | 2.0 | 2.0 | 4.5 | 7.0 | 12.3 | 18.8 | 3.8 | 7.5 | 12.2 | 22.0 | 28.0 | 29.8 |
| | **S4** | 2.0 | 2.0 | 2.7 | 5.0 | 9.2 | 16.2 | 2.2 | 4.0 | 8.3 | 17.0 | 24.0 | 25.5 |
| | **F1** | 2.0 | 2.0 | 2.2 | 5.3 | 8.3 | 14.7 | 2.0 | 3.3 | 6.8 | 11.7 | 17.3 | 18.8 |
| | **F2** | 2.0 | 2.0 | 2.0 | 2.8 | 6.0 | 9.3 | 2.0 | 2.0 | 5.0 | 8.0 | 13.2 | 17.0 |
| | **F3** | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 5.2 | 2.0 | 2.0 | 2.8 | 6.3 | 10.7 | 13.5 |
| | **F4** | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.7 | 2.0 | 2.0 | 3.2 | 6.5 | 9.8 | 11.3 |
| | **S1SD** | 2.0 | 2.0 | 5.7 | 9.7 | 19.7 | 28.3 | 3.0 | 6.3 | 11.0 | 22.5 | 29.5 | 30.5 |
| | **S2SD** | 2.0 | 2.3 | 6.5 | 12.0 | 21.7 | 30.5 | 3.5 | 7.5 | 12.0 | 25.2 | 32.3 | 34.0 |
| | **S3SD** | 2.0 | 3.0 | 7.3 | 12.8 | 22.2 | 31.0 | 2.8 | 6.2 | 12.0 | 23.3 | 30.3 | 32.2 |
| | **S4SD** | 2.0 | 2.3 | 6.3 | 10.5 | 19.2 | 28.5 | 3.8 | 7.7 | 13.7 | 25.2 | 32.7 | 33.5 |
| | **F1SD** | 2.0 | 2.0 | 5.7 | 9.0 | 15.2 | 22.2 | 2.0 | 3.5 | 7.5 | 12.5 | 19.5 | 21.2 |
| | **F2SD** | 2.0 | 2.0 | 5.0 | 7.8 | 14.7 | 22.7 | 2.3 | 3.3 | 6.7 | 14.2 | 21.3 | 22.8 |
| | **F3SD** | 2.0 | 2.0 | 5.5 | 7.8 | 14.0 | 22.7 | 2.2 | 3.2 | 8.2 | 12.8 | 20.5 | 23.3 |
| | **F4SD** | 2.0 | 2.0 | 5.2 | 7.2 | 12.5 | 20.3 | 2.0 | 2.2 | 5.8 | 9.3 | 14.2 | 16.7 |
| | **NF** | 2.0 | 2.0 | 6.2 | 8.8 | 14.8 | 17.5 | 2.5 | 5.0 | 9.7 | 14.3 | 14.7 | 14.7 |
| | **CF** | 2.0 | 5.3 | 10.8 | 20.8 | 36.5 | 48.0 | 5.5 | 9.8 | 20.3 | 37.5 | 44.0 | 46.8 |

| Years | Treatment | First repetition | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul | 8-Jul | 15-Jul | 22-Jul |
| 2017 | **S1** | 4.0 | 6.8 | 15.5 | 28.8 | 35.7 | 40.2 | 40.5 | 40.0 | 38.2 | 34.3 | 31.0 |
| | **S2** | 3.7 | 5.5 | 12.7 | 22.7 | 34.2 | 42.3 | 48.2 | 47.5 | 45.2 | 43.0 | 40.2 |
| | **S3** | 3.0 | 4.8 | 11.3 | 18.7 | 27.5 | 37.0 | 46.2 | 47.3 | 47.0 | 45.5 | 44.3 |
| | **S4** | 2.5 | 3.8 | 8.8 | 14.2 | 23.7 | 32.7 | 43.8 | 46.0 | 44.5 | 44.2 | 43.2 |
| | **F1** | 2.0 | 2.0 | 4.2 | 6.7 | 11.7 | 17.8 | 22.5 | 22.8 | 21.2 | 20.5 | 18.0 |
| | **F2** | 2.0 | 2.0 | 3.2 | 5.8 | 7.5 | 14.0 | 21.5 | 25.0 | 25.0 | 24.5 | 23.7 |
| | **F3** | 2.0 | 2.0 | 2.8 | 5.3 | 8.0 | 13.0 | 19.7 | 24.5 | 23.7 | 23.3 | 22.8 |
| | **F4** | 2.0 | 2.0 | 2.2 | 5.5 | 6.5 | 10.3 | 17.3 | 22.7 | 22.8 | 23.0 | 22.7 |
| | **S1SD** | 2.0 | 4.0 | 10.5 | 19.3 | 30.8 | 37.3 | 41.0 | 40.3 | 38.0 | 34.5 | 31.3 |
| | **S2SD** | 2.0 | 4.0 | 9.5 | 17.5 | 28.7 | 37.3 | 45.0 | 47.2 | 44.7 | 43.5 | 39.7 |
| | **S3SD** | 2.0 | 4.2 | 10.2 | 17.8 | 28.2 | 36.0 | 46.0 | 46.7 | 45.2 | 44.8 | 43.3 |
| | **S4SD** | 2.2 | 3.8 | 9.8 | 18.3 | 28.3 | 37.5 | 48.7 | 49.7 | 48.7 | 48.0 | 43.2 |
| | **F1SD** | 2.0 | 3.3 | 7.7 | 13.5 | 21.8 | 27.0 | 29.7 | 28.7 | 27.7 | 25.7 | 22.7 |
| | **F2SD** | 2.0 | 2.8 | 8.0 | 13.3 | 21.3 | 28.3 | 32.0 | 33.2 | 32.2 | 31.2 | 28.8 |
| | **F3SD** | 2.0 | 3.0 | 7.3 | 13.2 | 18.7 | 25.0 | 30.2 | 31.3 | 30.2 | 30.0 | 28.2 |
| | **F4SD** | 2.0 | 3.3 | 8.7 | 13.3 | 19.3 | 27.2 | 31.0 | 33.3 | 33.2 | 32.2 | 31.7 |
| | **NF** | 2.0 | 4.0 | 9.5 | 14.5 | 17.0 | 17.2 | 17.2 | 15.7 | 13.7 | 11.7 | 11.3 |
| | **CF** | 4.0 | 7.8 | 17.3 | 32.7 | 44.7 | 53.7 | 59.0 | 59.2 | 57.5 | 55.2 | 50.2 |

**Soil pH**

The changes in submerged soil pH in each treatment for six weeks are shown in Table 3.7. At 6 WAT. The soil pH was not influenced by different levels of SSC and FWC treatments whither by side dressing or uniform application method in two repetitions of 2016 and one repetition of 2017. The soil pH values of SSC and FWC treatments applied by side dressing or uniform application method were closed to neutral and increased numerically by increasing their levels in all repetitions. However, in comparison to CF treatments the soil pH of treatment CF was least than SSC and FWC treatments applied by side dressing or uniform application method in 2016 and 2017, and soil pH was tended to be acidic at first WAT and gradually soil pH was increased at 6 WAT (Table 3.7).

**Table 3.7 Soil pH in 2016 and 2017.**

| Years | | First repetition | | | | | | Second repetition | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 13-May | 20-May | 27-May | 3-Jun | 10-Jun | 17-Jun | 27-May | 3-Jun | 10-Jun | 17-Jun | 24-Jun | 1-Jul |
| 2016 | **S1** | 6.0 | 5.7 | 6.3 | 6.1 | 5.9 | 6.2 | 6.1 | 6.0 | 5.9 | 6.0 | N/A | N/A |
| | **S2** | 6.4 | 6.1 | 6.3 | 6.1 | 5.9 | 6.2 | 6.3 | 6.4 | 6.1 | 6.1 | N/A | N/A |
| | **S3** | 6.3 | 6.1 | 6.3 | 6.1 | 6.0 | 6.2 | 6.3 | 6.2 | 6.1 | 6.1 | N/A | N/A |
| | **S4** | 6.4 | 6.1 | 6.4 | 6.2 | 6.1 | 6.1 | 6.3 | 6.3 | 6.2 | 6.2 | N/A | N/A |
| | **F1** | 6.4 | 6.1 | 6.4 | 6.2 | 6.0 | 6.1 | 6.4 | 6.2 | 6.1 | 6.3 | N/A | N/A |
| | **F2** | 6.5 | 6.2 | 6.4 | 6.2 | 6.1 | 6.2 | 6.2 | 6.3 | 6.1 | 6.3 | N/A | N/A |
| | **F3** | 6.5 | 6.2 | 6.4 | 6.2 | 6.0 | 6.4 | 6.4 | 6.3 | 6.2 | 6.2 | N/A | N/A |
| | **F4** | 6.3 | 6.1 | 6.3 | 6.2 | 6.2 | 6.4 | 6.4 | 6.2 | 6.2 | 6.4 | N/A | N/A |
| | **S1SD** | 6.5 | 5.7 | 6.1 | 5.8 | 5.7 | 6.1 | 5.5 | 5.8 | 5.6 | 6.1 | N/A | N/A |
| | **S2SD** | 6.1 | 5.7 | 6.2 | 6.0 | 5.8 | 6.0 | 5.5 | 5.9 | 5.7 | 6.0 | N/A | N/A |
| | **S3SD** | 6.2 | 5.7 | 6.2 | 5.9 | 5.8 | 6.6 | 5.8 | 5.7 | 5.7 | 5.9 | N/A | N/A |
| | **S4SD** | 6.1 | 5.7 | 6.3 | 6.0 | 5.8 | 6.0 | 5.9 | 6.3 | 5.9 | 6.1 | N/A | N/A |
| | **F1SD** | 6.3 | 6.0 | 6.2 | 6.2 | 5.8 | 6.2 | 6.0 | 6.0 | 5.8 | 6.1 | N/A | N/A |
| | **F2SD** | 6.4 | 6.1 | 6.3 | 6.1 | 5.9 | 6.2 | 5.9 | 5.9 | 5.8 | 6.1 | N/A | N/A |
| | **F3SD** | 6.1 | 5.9 | 6.3 | 6.1 | 5.8 | 6.2 | 6.1 | 6.1 | 6.1 | 6.2 | N/A | N/A |
| | **F4SD** | 6.2 | 5.9 | 6.5 | 6.2 | 6.0 | 6.2 | 6.1 | 6.2 | 6.1 | 6.2 | N/A | N/A |
| | **NF** | 6.3 | 5.6 | 6.1 | 5.8 | 5.6 | 6.0 | 5.6 | 5.7 | 5.5 | 5.9 | N/A | N/A |
| | **CF** | 4.8 | 5.1 | 5.4 | 5.4 | 4.6 | 5.5 | 5.5 | 5.1 | 4.7 | 5.2 | N/A | N/A |

| Years | | First repetition | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Treatment | 8-May | 12-May | 19-May | 26-May | 2-Jun | 9-Jun | 16-Jun | 23-Jun |
| 2017 | **S1** | 5.6 | 5.6 | 5.7 | 5.5 | 5.5 | 5.3 | 5.4 | 5.6 |
| | **S2** | 5.8 | 5.9 | 6.1 | 5.8 | 5.6 | 5.4 | 5.6 | 5.7 |
| | **S3** | 5.8 | 6.0 | 6.2 | 5.9 | 5.7 | 5.5 | 5.6 | 5.6 |
| | **S4** | 6.0 | 6.1 | 6.3 | 5.9 | 5.8 | 5.4 | 5.5 | 5.6 |
| | **F1** | 5.9 | 6.1 | 6.1 | 5.8 | 5.8 | 5.7 | 5.7 | 5.9 |
| | **F2** | 6.2 | 6.0 | 6.2 | 5.9 | 5.9 | 5.7 | 5.8 | 6.0 |
| | **F3** | 6.2 | 6.0 | 6.2 | 5.9 | 5.9 | 5.7 | 5.9 | 6.0 |
| | **F4** | 6.3 | 6.0 | 6.3 | 6.0 | 5.9 | 5.7 | 5.9 | 6.1 |
| | **S1SD** | 5.9 | 5.3 | 5.4 | 5.3 | 5.5 | 5.2 | 5.2 | 5.6 |
| | **S2SD** | 5.7 | 5.4 | 5.5 | 5.3 | 5.3 | 5.0 | 5.4 | 5.7 |
| | **S3SD** | 5.7 | 5.3 | 5.5 | 5.4 | 5.5 | 5.3 | 5.5 | 5.7 |
| | **S4SD** | 5.6 | 5.1 | 5.5 | 5.4 | 5.4 | 5.2 | 5.5 | 5.7 |
| | **F1SD** | 5.9 | 5.3 | 5.4 | 5.6 | 5.5 | 5.3 | 5.5 | 5.7 |
| | **F2SD** | 6.0 | 5.1 | 5.4 | 5.4 | 5.6 | 5.5 | 5.7 | 5.9 |
| | **F3SD** | 5.6 | 5.0 | 5.4 | 5.5 | 5.6 | 5.5 | 5.8 | 6.0 |
| | **F4SD** | 6.0 | 5.3 | 5.6 | 5.7 | 5.8 | 5.6 | 5.9 | 6.1 |
| | **NF** | 5.4 | 5.1 | 5.0 | 4.7 | 4.7 | 3.9 | 3.9 | 4.7 |
| | **CF** | 5.6 | 5.4 | 5.6 | 5.4 | 5.4 | 5.3 | 5.4 | 5.8 |

N/A: Data not available.

**Dry matter production**

The dry matter production (g hill$^{-1}$) of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) of two repetitions in 2016 are demonstrated in Table 3.8.

In 2016, the dry weight of leaf blade, leaf sheath, top, root and T-R ratio were differ by different composts (SSC and FWC), their levels and methods of application. The dry weight of top which included leaf blade and leaf sheath in CF treatment was significantly ($p$<0.05) heavier than all SSC and FWC treatments applied by side dressing or uniform application method in both repetitions in 2016. The dry matter production of both top and root were depressed by increasing the amount (N level) of SSC or FWC applied by uniform application in both repetitions. The significantly higher dry weight of top and root were recorded with treatments $S_1$ and $F_1$, and the lower were registered with treatments $S_4$ and $F_4$. The degree of depression was larger in FWC treatments than SSC treatments. TR ratio of CF treatment in the first repetition was significantly larger than all FWC treatments applied by side dressing or uniform application, Treatments $S_1$, $S_1$SD and NF, but in second repetition the T-R ratio of CF treatment was similar to all treatments except treatments NF and $F_1$SD, $S_1$SD, $F_1$ and $S_1$.

Regarding the uniform application method, top and root dry weight of rice plants in first and second repetitions in 2016 depressed by increasing the N levels (amount) of SSC or FWC. On the other hand, top and root of rice plants cultivated with side dressing did not significantly differ among different levels of SSC and FWC treatments in first and second repetitions in 2016. It indicates that the side dressing method reduced the inhibition effects with different levels of both composts. Though, FWC treatments caused greater inhibition of top and root growth than SSC treatments in both repetitions, lower N levels (amount) of both composts produced commonly heavier dry matter than that of higher N levels (Table 3.8). It was found from the result of this study that different application methods of SSC and FWC with their levels obviously effect on dry matter production of rice. In general, dry matter production of SSC treatments were performed better than FWC treatments and one side application is better than uniform application. Biomass produced in the first repetition, which was popular time for rice transplanting in Mie prefecture in Japan, recorded smaller than later transplanting dates (second) (Table 3.8).

**Table 3.8 Dry matter production (g hill$^{-1}$) at early growth stage in 2016.**

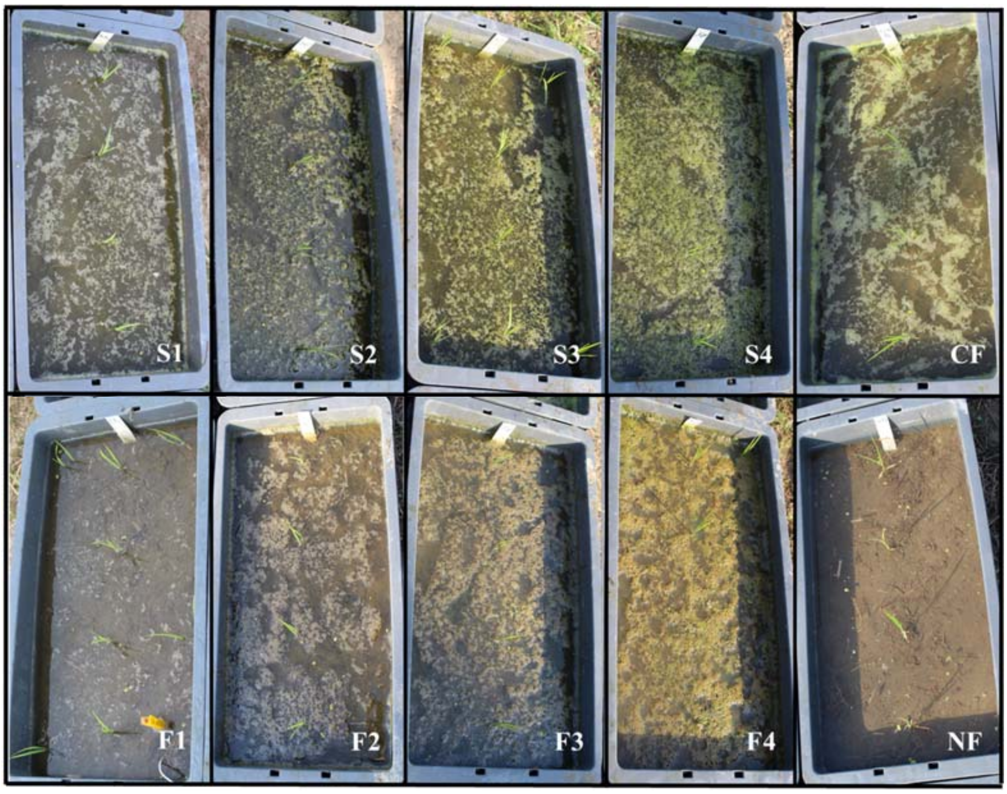
| Repetition | Treatments | L.B | L.S | Top | Root | T-R ratio** |
|---|---|---|---|---|---|---|
| | **$S_1$** | 7.0 | 7.2 | 14.2 e | 2.9 d | 4.9 ab |
| | **$S_2$** | 5.1 | 4.9 | 10.0 d | 1.7 bc | 6.0 bc |
| | **$S_3$** | 4.4 | 4.3 | 8.7 cd | 1.5 bc | 5.7 bc |
| | **$S_4$** | 3.8 | 3.6 | 7.4 cd | 1.3 b | 5.7 bc |
| | **$F_1$** | 2.7 | 2.8 | 5.5 bc | 1.2 ab | 4.5 ab |
| | **$F_2$** | 1.7 | 1.6 | 3.3 ab | 0.7 ab | 4.5 ab |
| | **$F_3$** | 0.7 | 0.6 | 1.3 a | 0.4 a | 3.5 a |
| | **$F_4$** | 0.4 | 0.4 | 0.8 a | 0.2 a | 4.8 ab |
| **First** | **$S_1$SD** | 6.9 | 7.4 | 14.3 e | 2.6 cd | 5.5 b |
| (23 June)* | **$S_2$SD** | 7.6 | 8.0 | 15.6 e | 2.3 c | 6.7 c |
| | **$S_3$SD** | 7.9 | 8.1 | 16.0 e | 2.3 c | 7.1 c |
| | **$S_4$SD** | 7.1 | 7.1 | 14.3 e | 1.9 c | 7.4 c |
| | **$F_1$SD** | 4.7 | 5.3 | 10.0 d | 2.2 c | 4.8 ab |
| | **$F_2$SD** | 5.1 | 5.2 | 10.3 d | 1.8 bc | 5.9 bc |
| | **$F_3$SD** | 4.9 | 5.4 | 10.3 d | 1.8 bc | 5.6 b |
| | **$F_4$SD** | 4.1 | 4.4 | 8.5 cd | 1.5 bc | 5.6 b |
| | **NF** | 2.7 | 4.4 | 7.1 bcd | 2.4 cd | 2.9 a |
| | **CF** | 13.0 | 13.6 | 26.6 f | 3.5 d | 7.8 c |
| | **$S_1$** | 10.6 | 16.4 | 27.0 c | 4.8 c | 5.8 ab |
| | **$S_2$** | 11.0 | 13.4 | 24.4 bc | 3.6 bc | 6.8 bc |
| | **$S_3$** | 11.3 | 12.6 | 23.9 bc | 3.0 ab | 8.2 c |
| | **$S_4$** | 9.6 | 11.1 | 20.7 bc | 2.6 ab | 7.9 c |
| | **$F_1$** | 5.7 | 8.7 | 14.4 ab | 2.9 ab | 5.1 ab |
| | **$F_2$** | 5.1 | 6.4 | 11.5 a | 1.9 ab | 6.2 abc |
| | **$F_3$** | 4.3 | 5.3 | 9.6 a | 1.3 a | 7.3 bc |
| | **$F_4$** | 2.9 | 3.4 | 6.3 a | 1.1 a | 5.8 ab |
| **Second** | **$S_1$SD** | 10.3 | 14.7 | 25.0 bc | 3.8 bc | 6.6 bc |
| (07 July)* | **$S_2$SD** | 12.6 | 15.9 | 28.5 c | 4.1 bc | 7.1 bc |
| | **$S_3$SD** | 12.3 | 15.5 | 27.8 c | 3.8 bc | 7.4 bc |
| | **$S_4$SD** | 13.8 | 16.5 | 30.3 c | 3.5 abc | 8.7 c |
| | **$F_1$SD** | 6.2 | 9.4 | 15.6 ab | 3.0 ab | 5.5 ab |
| | **$F_2$SD** | 7.5 | 9.8 | 17.3 ab | 2.5 ab | 7.0 bc |
| | **$F_3$SD** | 7.3 | 9.4 | 16.7 ab | 2.5 ab | 6.7 bc |
| | **$F_4$SD** | 5.2 | 6.3 | 11.5 a | 1.9 ab | 6.3 bc |
| | **NF** | 3.1 | 6.1 | 9.2 a | 2.8 ab | 3.5 a |
| | **CF** | 19.7 | 26.2 | 45.9 d | 5.5 c | 8.4 c |

* Date of sampling. ** The Top-Root ratio.
Data represent mean (n=3). Means within each column with the same letter(s) are not significantly different at *P*<0.05, using Tukey multiple comparisons test.

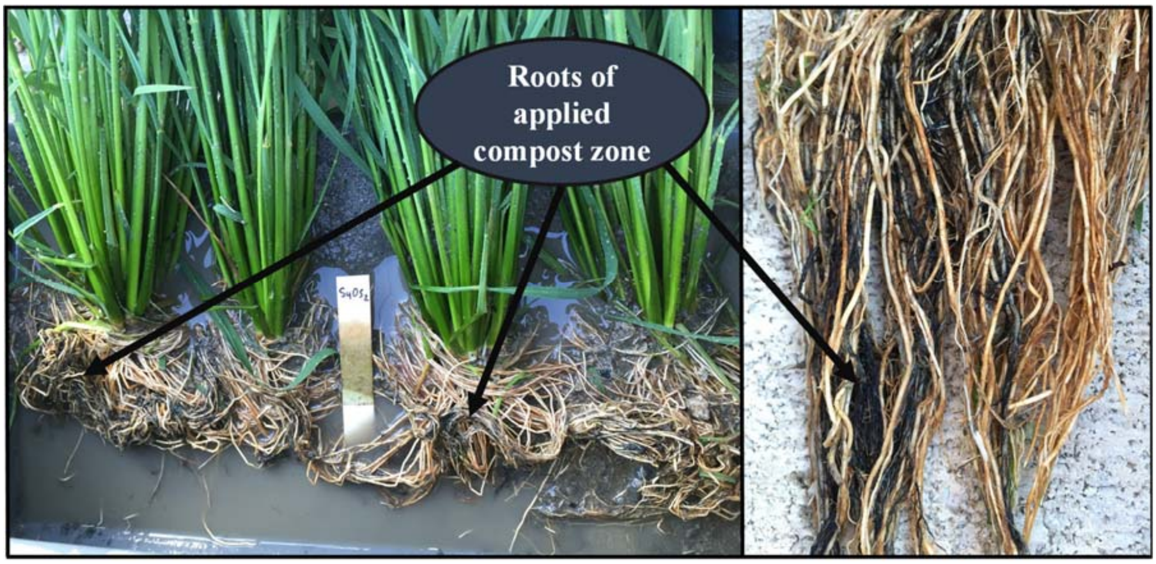
Picture 3.1 shows the soil condition of SSC treatments ($S_1$, $S_2$, $S_3$ and $S_4$), FWC treatments ($F_1$, $F_2$, $F_3$ and $F_4$), control treatment CF and NF treatment at one WAT. Basal compost application caused an abnormal condition in the soil by putrefying soil and water, changing their color and smell at the initial growth stage. The situation got worse by increasing the amount of compost, particularly FWC. This condition prevented root growth and development, and the rice plants which were sensitive at this stage could not grew properly (Pictures 3.1).

Picture 3.2 shows the root condition based on different method of compost application. The root growth and development of side dressing was seen healthier than that uniform application. According to visual observation, in the side dressing method, the roots of unapplied compost zone were grown and developed better than the roots of applied compost zone (Pictures 3.2).

**Picture 3.1 Different soil condition caused by different compost application.**




**Picture 3.2 shows the root condition of compost applied zone and no compost application zone.**



**Heading stage and maturity stage**

Table 3.9 shows the days of heading stage and maturity stage of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2017.

Side dressing and uniform application methods of SSC and FWC influenced the duration from transplanting to heading stage and heading stage to maturity stage. In 2017, the duration from transplanting to heading stage of SSC treatments applied by uniform application method was shorter than the SSC applied by side dressing method. However, the duration from transplanting to heading stage of FWC treatments applied by uniform application method was longer than the FWC applied by side dressing method except treatment $F_1$SD. For instance, the heading stage of treatments $S_1$ and $F_1$ were 79 and 80 days after transplanting but the heading stage of treatments $S_1$SD and $F_1$SD were 81 and 81 days after transplanting.

In comparison to different N levels (amount of compost), the days from transplanting to heading stage of SSC and FWC treatments elongated by increasing their levels. The minimum number of days from transplanting to heading stage among SSC treatments applied by uniform application method was found in treatment $S_1$ (79), it was followed by treatments $S_2$ and $S_3$ (80 and 82, respectively) and the maximum was found in treatment $S_4$ (83). The days from transplanting to heading stage among SSC treatments applied by side dressing method was found 81 days in treatment $S_1$SD, it was closely followed by treatments $S_2$SD (82) and the maximum was with treatments $S_3$SD and $S_4$SD (83 and 83, respectively).

Meanwhile, the number of days from transplanting to heading stage in FWC treatments applied by uniform application was recorded minimum in treatment $F_1$ (80), followed by treatments $F_2$ and $F_3$ (83 and 83, respectively) and the maximum was found in treatment $F_4$ (84). However, there was no different between FWC treatments applied by side dressing application. In comparison to control treatment CF, the duration between transplanting to heading stage of treatments $S_4$, $F_2$, $F_3$, $F_4$, $S_3$SD and $S_4$SD were found longer (83, 83, 83, 84, 83 and 83, respectively) than CF (82).

Date of maturity of SSC treatments applied by uniform application was longer in treatment $S_4$ (31-August), followed by treatment $S_3$ and $S_2$ (29-August and 26-August, respectively, however date of maturity was shorter in treatment $S_1$ (23-August). As well, date of maturity of SSC treatments applied by side dressing method was longer in treatment $S_4$SD (30-August), followed by treatment $S_3$SD and $S_2$SD (28-August and 27-August, respectively, however date of maturity was shorter in treatment $S_1$SD (26-August). Meanwhile, date of maturity of FWC treatments applied by uniform application method was longer in treatment $F_4$ (30-August), followed by treatment $F_3$ (29-August) and treatment $F_2$ (28-August) however, date of maturity was shorter in treatment $F_1$ (25-August). But date of maturity of FWC treatments applied by side dressing method were not differ so long, treatments $F_1$SD and $F_2$SD matured on 26-August and treatments $F_3$SD and $F_4$SD matured on 27-August.

In comparison to control treatment CF and NF, except treatments $S_1$ and $S_2$, $F_1$, $S_1$SD, $F_1$SD and $F_2$SD the maturity date of all other SSC and FWC treatments applied by side dressing or uniform application method were found longer than control treatment CF. All treatments except $S_1$ were also longer than treatment NF (Table 3.9).

**Table 3.9 Days of heading stage and maturity stage in 2017.**

| Treatments | Heading stage* | Maturity stage** |
|---|---|---|
| **$S_1$** | 17-Jul (79) | 23-Aug (37) |
| **$S_2$** | 18-Jul (80) | 26-Aug (39) |
| **$S_3$** | 20-Jul (82) | 29-Aug (40) |
| **$S_4$** | 21-Jul (83) | 31-Aug (41) |
| **$F_1$** | 18-Jul (80) | 25-Aug (38) |
| **$F_2$** | 21-Jul (83) | 28-Aug (38) |
| **$F_3$** | 21-Jul (83) | 29-Aug (39) |
| **$F_4$** | 22-Jul (84) | 30-Aug (39) |
| **$S_1$SD** | 19-Jul (81) | 26-Aug (38) |
| **$S_2$SD** | 20-Jul (82) | 27-Aug (38) |
| **$S_3$SD** | 21-Jul (83) | 28-Aug (38) |
| **$S_4$SD** | 21-Jul (83) | 30-Aug (40) |
| **$F_1$SD** | 19-Jul (81) | 26-Aug (38) |
| **$F_2$SD** | 19-Jul (81) | 26-Aug (38) |
| **$F_3$SD** | 19-Jul (81) | 27-Aug (39) |
| **$F_4$SD** | 19-Jul (81) | 27-Aug (39) |
| **NF** | 18-Jul (80) | 24-Aug (37) |
| **CF** | 20-Jul (82) | 26-Aug (37) |

*Data shown in parentheses are days from transplanting to heading stage. **Data shown in parentheses are days from heading stage to maturity stage.

**Soil-plant analysis development (SPAD) value**

Table 3.10 indicates the soil-plant analysis development (SPAD) values of uppermost 3 leaves (flag leaf, 2nd leaf and 3rd leaf) of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2017. SPAD values of flag leaf, 2nd leaf and 3rd leaf were obviously differ among different N levels (amount) at heading stage and 10 days after heading stage but different composts (SSC and FWC) and different method of application did not show big difference.

At heading stage, the significantly greater SPAD values of flag leaf, 2$^{nd}$ leaf and 3$^{rd}$ leaf were observed in high N level of SSC treatment $S_4$ (42.5, 46.1 and 46.4 respectively) and FWC treatment $F_4$ (44.3, 45.0 and 44.3, respectively) and the lowest was recorded in low level of SSC treatment $S_1$ (35.5, 34.4 and 34.5, respectively) and FWC treatment $F_1$ (34.6, 33.8 and 33.6 respectively) with uniform application method. The same trend was recorded with side dressing method, the higher N levels registered high SPAD value and the lower N levels recorded low SAPD value. However, control treatment CF recorded higher SPAD values of flag leaf, 2$^{nd}$ leaf and 3$^{rd}$ leaf (41.9, 46.0 and 46.8, respectively) than low levels of SSC and FWC applied by whether side dressing or uniform application method. But the high level of composts were at par with CF treatment. Treatment NF was significantly recorded lower SPAD value than all other treatments.

At 10 days and 20 days after heading stage, the mean SPAD values of flag leaf, 2$^{nd}$ leaf and 3$^{rd}$ leaf shown the same trend as heading stage, but the mean SPAD values of flag leaf, 2nd leaf and 3rd at 20 days after heading stage were lower than heading stage and 10 days after heading stage (Table 3.10). Therefore, it is signify that the SPAD values of uppermost three leaves decreased in 20 days after heading stage.

**Table 3.10 Soil-plant analysis development (SPAD) value in 2017.**

| Treatment | Heading Stage | | | 10 days after Heading stage | | | 20 days after heading stage | | |
|---|---|---|---|---|---|---|---|---|---|
| | F.L* S.D | S.L** S.D | T.L*** S.D | F.L* S.D | S.L** S.D | T.L*** S.D | F.L* S.D | S.L** S.D | T.L*** S.D |
| **S1** | 35.5 ± 1.6 ab | 34.4 ± 0.5 b | 34.5 ± 1.2 b | 35.8 ± 0.8 ab | 33.7 ± 1.3 b | 31.0 ± 2.8 b | 29.7 ± 1.4 | 20.4 ± 3.5 | 22.6 ± 0.5 |
| **S2** | 38.7 ± 1.3 bcd | 40.3 ± 1.1 cd | 42.0 ± 2.9 cd | 40.1 ± 1.3 c | 41.9 ± 1.4 de | 37.9 ± 2.1 cd | 36.4 ± 1.6 | 33.1 ± 2.8 | 26.5 ± 2.7 |
| **S3** | 42.2 ± 0.9 d | 43.8 ± 1.0 def | 44.9 ± 1.2 def | 43.9 ± 1.3 cde | 43.9 ± 0.4 ef | 42.3 ± 2.1 de | 41.7 ± 1.1 | 39.2 ± 3.4 | 31.4 ± 9.9 |
| **S4** | 42.5 ± 1.1 d | 46.1 ± 0.6 f | 46.4 ± 0.3 ef | 44.8 ± 0.9 de | 46.3 ± 0.5 f | 43.8 ± 1.1 e | 42.1 ± 1.2 | 41.1 ± 1.5 | 38.8 ± 1.6 |
| **F1** | 34.6 ± 1.0 ab | 33.8 ± 1.9 b | 33.6 ± 0.8 b | 34.6 ± 1.3 ab | 34.2 ± 1.7 b | 30.9 ± 0.5 b | 30.9 ± 0.7 | 23.7 ± 3.5 | 22.0 ± 1.6 |
| **F2** | 36.9 ± 1.4 bc | 37.7 ± 0.8 c | 39.2 ± 1.0 c | 36.7 ± 1.6 b | 37.1 ± 0.2 bc | 34.5 ± 1.1 bc | 30.2 ± 3.6 | 24.5 ± 4.4 | 20.5 ± 2.5 |
| **F3** | 41.4 ± 4.9 cd | 42.5 ± 1.4 de | 42.9 ± 3.1 cde | 41.7 ± 3.4 cd | 41.4 ± 3.1 cde | 38.5 ± 4.0 cd | 36.7 ± 5.4 | 28.4 ± 7.1 | 24.2 ± 4.8 |
| **F4** | 44.3 ± 2.1 d | 45.0 ± 0.5 ef | 44.3 ± 0.3 def | 44.1 ± 2.3 cde | 43.8 ± 0.8 ef | 42.5 ± 0.4 de | 39.4 ± 2.1 | 36.4 ± 3.8 | 30.1 ± 3.5 |
| **S1SD** | 36.9 ± 0.7 bc | 37.0 ± 1.0 bc | 37.6 ± 0.5 b | 36.9 ± 0.8 b | 36.7 ± 0.2 b | 34.0 ± 0.8 bc | 32.3 ± 1.2 | 25.2 ± 2.9 | 22.8 ± 2.2 |
| **S2SD** | 40.7 ± 0.4 cd | 42.4 ± 1.2 de | 44.2 ± 1.0 def | 41.7 ± 1.0 cd | 41.9 ± 0.4 de | 39.9 ± 1.2 d | 38.2 ± 1.0 | 35.9 ± 2.0 | 25.6 ± 3.8 |
| **S3SD** | 44.2 ± 1.1 d | 46.6 ± 1.2 f | 47.3 ± 0.4 f | 45.5 ± 0.4 de | 46.3 ± 0.3 f | 45.8 ± 0.6 e | 41.0 ± 0.8 | 39.8 ± 0.9 | 34.4 ± 1.4 |
| **S4SD** | 43.9 ± 0.9 d | 48.6 ± 2.1 f | 47.9 ± 2.0 f | 46.4 ± 0.4 e | 47.8 ± 1.3 f | 47.3 ± 0.1 e | 44.9 ± 0.2 | 44.1 ± 1.0 | 40.7 ± 1.4 |
| **F1SD** | 34.6 ± 0.8 ab | 34.3 ± 1.1 b | 33.4 ± 0.6 b | 34.3 ± 1.0 ab | 33.9 ± 2.5 b | 30.3 ± 1.6 b | 28.3 ± 2.0 | 22.6 ± 2.9 | 20.2 ± 0.7 |
| **F2SD** | 37.5 ± 1.1 bc | 39.1 ± 1.1 cd | 38.9 ± 1.1 c | 37.8 ± 1.3 b | 37.8 ± 1.4 bcd | 34.4 ± 2.2 bc | 32.2 ± 0.6 | 26.4 ± 4.3 | 21.6 ± 2.4 |
| **F3SD** | 40.8 ± 1.1 cd | 42.2 ± 0.9 de | 42.2 ± 1.2 cd | 41.3 ± 2.3 cd | 42.2 ± 1.7 de | 39.1 ± 1.9 cd | 37.2 ± 2.6 | 34.5 ± 4.2 | 27.6 ± 4.3 |
| **F4SD** | 43.8 ± 0.8 d | 44.6 ± 0.8 ef | 44.5 ± 0.9 def | 44.5 ± 0.2 de | 45.2 ± 1.1 ef | 42.6 ± 0.5 de | 41.3 ± 0.4 | 41.1 ± 1.3 | 33.0 ± 3.1 |
| **NF** | 31.7 ± 0.4 a | 27.9 ± 1.0 a | 25.7 ± 1.5 a | 31.9 ± 0.5 a | 26.6 ± 1.0 a | 23.0 ± 1.6 a | 25.2 ± 1.4 | 17.3 ± 2.3 | 15.1 ± 2.2 |
| **CF** | 41.9 ± 1.1 d | 46.0 ± 0.9 f | 46.8 ± 1.0 ef | 42.4 ± 0.4 cde | 44.7 ± 2.7 ef | 41.4 ± 2.0 d | 37.4 ± 3.8 | 33.3 ± 1.4 | 24.9 ± 1.7 |

* Flag leaf. ** Top second leaf. *** Top third leaf. **S.D** means ± standard deviation.

Means within each column with the same letter(s) are not significantly different at $P<0.05$, using Tukey multiple comparisons test.

**Effects on yield components**

From the result of this study in 2017, it was found that different application methods (side dressing and uniform application), different composts (SSC and FWC), and different N levels (amount of compost) had obviously effected on yield components of rice. Top air-dry weight, weight of winnowed rough rice, straw weight, number of productive panicle, average number of spikelet per panicle, percentage of ripened grains, 1000-winnowed rough rice weight, culm length, panicle length, internodes length, maximum tiller number per hill, number of grain per panicle and percentage of productive culms were differ by different application methods, different composts, and different N levels. In general, yield components of SSC treatments were performed better than FWC treatments and side dressing method than uniform application method.

The yield components of SSC treatments applied by uniform application method ($S_1$, $S_2$, $S_3$ and $S_4$), SSC treatments applied by side dressing method ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD), FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$), FWC treatments applied by side dressing method ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD), chemical fertilizer treatment (CF) and no fertilizer treatment (NF) in 2017 indicated in Table 3.11.

**Top air-dry weight per hill (g)**

Top air-dry weight was differ among different methods of application, different types of compost and their levels. The top air-dry weight was increased with the increase in the amount of SSC and FWC applied by uniform application method, the maximum was recorded in treatments $S_3$ and $F_4$ (128.9 and 89.4 g, respectively) which were at pat with treatments $S_4$ and $S_2$; and $F_3$ and $F_2$ however, the significantly minimum was registered with treatment $S_1$ and F1 (72.6 and 46.5 g, respectively). The same trend was recorded with side dressing method of SSC and FWC, the top air-dry weight of SSC and FWC treatments applied by side dressing method were also increased by increasing their amount, the maximum was recorded in treatment $S_4SD$ and $F_4SD$ (130.3 and 98.9 g, respectively) which were significantly equal with treatments $S_3SD$ and $S_2SD$; and $F_3SD$ and $F_2SD$, but the significantly minimum was registered with treatments $S_1SD$ and $F_1SD$ (84.6 and 54.5 g respectively). Though, SSC treatments produced higher top air-dry weight than FWC treatments and side dressing method then uniform application method. Top air-dry weight of treatments $S_4$, $S_3$, $S_2$, $S_4SD$, $S_3SD$ and $S_2SD$ were found significantly at par with the control treatment CF (114.8 g), the rest of the treatments were lower. The significantly minimum air-dry weight was counted in treatment NF (25.9 g) (Table 3.11).

**Weight of winnowed rough rice (Yield) (dry weight, g hill$^{-1}$)**

The dry weight of winnowed rough rice per hill (yield) was differ among different methods of application, different types of compost and their levels. Among SSC and FWC treatments applied by uniform application method, the maximum yield was recorded in treatments $S_3$ and $F_4$ (42.7 and 36.6 g, respectively) which were at par with treatments $S_4$ and $S_2$; and $F_3$ and $F_2$ however, the significantly minimum was registered with treatments $S_1$ and F1 (29.6 and 19.7 g, respectively). The same trend was recorded with side dressing method of SSC and FWC application. SSC treatments $S_1$, $S_3$, $S_1SD$ and $S_2SD$ were significantly higher than the same N levels of FWC treatments $F_1$, $F_3$, $F_1SD$ and $F_2SD$, it means that the SSC treatments produced more yield then the FWC treatments.

Among all treatments, the yield of treatments $S_2$, $S_3$, $S_4$, $F_4$, $S_2SD$, $S_3SD$, $S_4SD$, $F_3SD$ and $F_4SD$ (37.8, 42.7, 35.4, 36.6, 43.5, 48.2, 42.7, 41.4 and 41.5 g, respectively) were found significantly higher than control treatment CF (23.7 g). In comparison to different application methods, the yield of FWC treatment $F_3SD$ was significantly higher than treatment $F_3$, and the yield of rest of SSC and FWC treatments with side dressing method at each N level were numerically larger than that of the uniform application method. The yield of treatment NF (10.6 g) registered significantly minimum than all other treatments (Table 3.11).

**Number of productive panicle per hill**

Number of productive panicle was differ among different methods of application, different types of compost and their levels.

Within SSC treatments applied by uniform application method, the maximum number of productive panicle was registered in treatment $S_3$ (40.7), which was at par with treatments $S_4$, $S_2$ and CF (37.3, 36.2 and 40.0, respectively) however, the significantly minimum was counted in treatment $S_1$ (25.8). Meanwhile, number of productive panicle of FWC treatments applied by uniform application method ($F_1$, $F_2$, $F_3$ and $F_4$) did not significantly differ with each other (16.0, 20.0, 22.3 and 22.0, respectively) but, all FWC treatments were significantly smaller than control treatment CF (40.0) and higher than treatment NF (9.2).

Within SSC treatments applied by side dressing method, number of productive panicle of treatments $S_2SD$, $S_3SD$, $S_4SD$ and CF (35.8, 38.0, 41.2 and 40.0, respectively) were registered similar with each other, but significantly higher than treatment $S_1SD$ (26.3). As well, number of productive panicle of FWC treatments applied by side dressing method ($F_1SD$, $F_2SD$, $F_3SD$ and $F_4SD$) was registered maximum with treatment $F_4SD$ (29.7) which was at par with treatments $F_2SD$ and $F_3SD$ (25.8 and 26.8, respectively) and the significantly minimum was recorded in treatment $F_1SD$ (18.3). All FWC treatments applied by whether uniform application or side dressing method were found significantly lower than control treatment CF (40) and higher than treatments NF (9.2). The number of productive panicle of FWC treatments $F_2$SD, $F_3$SD and $F_4$SD (25.8, 26.8 and 29.7 respectively) applied by side dressing method were found significantly higher than the FWC treatments $F_2$, $F_3$ and $F_4$ (16.0, 20.0 and 23.3 respectively) applied by uniform application method therefore side dressing method perform better than uniform application method (Table 3.11).

**Average number of spikelet per panicle**

Average number of spikelet per panicle was differ with different methods of application, different types of compost and their levels.

With uniform application method, the significantly maximum average number of spikelet per panicle of SSC treatments was registered in treatment $S_4$ (94.3), followed by treatments $S_3$ and $S_2$ (83.8 and 72.9, respectively) and the minimum was counted in treatment $S_1$ (63.7). As well, the average number of spikelet per panicle of FWC treatments, recorded higher in treatment $F_4$ (111.8), followed by treatments $F_3$ and $F_2$ (98.0 and 85.9, respectively) and the significantly lower was registered in treatment $F_1$ (70.3). Control treatment CF (78.6) was found at par with treatments $S_2$, $S_3$, $F_1$ and $F_2$ but higher than treatment $S_1$. Treatments $S_4$, $F_3$ and $F_4$ were recorded significantly higher average number of spikelet per panicle than control treatments CF. Treatment NF was recorded the significantly lower average number of spikelet per panicle than all SSC and FWC treatments applied by uniform application method except treatment $S_1$ which was at par with.

With side dressing method, average number of spikelet per panicle of SSC treatments $S_2$SD, $S_3$SD and $S_4$SD (80.6, 84.7 and 85.4, respectively) were found higher and at par with each other however, treatment $S_1$SD (69.3) was recorded significantly lower. As well, the average number of spikelet per panicle of FWC treatments $F_3SD$ and $F_4SD$ (88.6 and 83.1, respectively) were found at par with each other and significantly maximum than treatments $F_2SD$ and $F_1SD$ (71.9 and 63.0, respectively). In comparison to CF treatment, the average number of spikelet per panicle of all SSC and FWC treatments applied with side dressing method were found at par with treatment CF (78.6) except treatments $S_1SD$ and $F_1SD$. The average number of spikelet per panicle of SSC and FWC treatments $S_2$, $S_4$, $F_2$, $F_3$ and $F_4$ (72.9, 94.3, 85.9, 98.0 and 111.8 respectively) applied by uniform application method were found significantly higher than the same levels of SSC and FWC treatments $S_2SD$, $S_4SD$, $F_2SD$, $F_3SD$ and $F_4SD$ (80.6, 85.4, 71.9, 88.6 and 83.1 respectively) applied by side dressing method therefore, uniform application method perform better in average number of spikelet per panicle than side dressing method (Table 3.11).

**Percentage of ripened grains (%)**

Percentage of ripened grains was differ with different methods of application, different types of compost and decreased by increasing the N levels (amount) of composts.

With uniform application method, the significantly maximum percentage of ripened grains of SSC treatments was registered in treatment $S_1$ (81.7) which was at par with treatment $S_2$ (69.4) and the significantly minimum was counted in treatment $S_4$ (48.5) which was at par with treatment $S_3$ (60.6). However, the percentage of ripened grains of FWC treatments did not significantly differ with each other but numerically decreased by increasing the N level of FWC. Percentage of ripened grains of all SSC and FWC treatments applied by uniform application method were registered significantly higher than control treatment CF (38.1). However, treatment NF recorded the significantly highest percentage of ripened grains (88.5) than all SSC and FWC treatments, except treatments $S_1$ and $F_1$ which were found at par with treatments NF.

With side dressing method, percentage of ripened grains of SSC treatments $S_1$SD, $S_2$SD and $S_3$SD (84.5, 72.8 and 71.0, respectively) were found higher and at par with each other, and treatment $S_4$SD (57.1) recorded the significantly lower. However, the percentage of ripened grains of FWC treatments applied by side dressing method did not differ with each other although, numerically the percentage of ripened grains increased by decreasing the N level of FWC. In comparison to CF treatment, the percentage of ripened grains of all SSC and FWC treatments applied with side dressing method were found significantly higher treatment CF (38.1). The percentage of ripened grains of all FWC treatments and treatment $S_1$SD were at par with NF (Table 3.11).

**1000-winnowed rough rice (dry weight, g)**

1000-winnowed rough rice weight was differ with different methods of application, different types of compost and the N levels (amount) of composts.

Within SSC treatments applied by uniform application method, the maximum weight of 1000-winnowed rough rice was registered in treatment $S_1$ (22.1 g) which was at par with treatment $S_2$ (20.7 g) however, the significantly minimum was counted in treatment $S_3$ (20.6 g) which was at par with treatments $S_4$ (20.7 g). Meanwhile, 1000-winnowed rough rice weight of FWC treatments $F_1$, $F_2$ and $F_3$ applied by uniform application method did not significantly differ with each other (21.5, 21.1 and 22.0 g, respectively) but, treatment $F_4$ registered the significantly maximum (22.8 g). 1000-winnowed rough rice weight of SSC treatments were decreased by increasing the N level of compost while, weight of 1000-

winnowed rough rice increased by increasing the N level of FWC. Weight of 1000-winnowed rough rice of all SSC and FWC treatments applied by uniform application method were found significantly higher than control treatment CF (19.7 g) but they were smaller than treatment NF (23.6 g) except treatment $F_4$ which was at par with NF.

Within SSC and FWC treatments applied by side dressing method, 1000-winnowed rough rice weight of SSC treatments ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) and FWC treatments ($F_1$SD, $F_2$SD, $F_3$SD and $F_4$SD) did not significantly differ with each other but weight of 1000-winnowed rough rice of FWC treatments were higher than SSC treatments. For instant, treatments $F_3$SD and $F_4$SD have recorded significantly higher weight of 1000-winnowed rough rice than treatments $S_3$SD and $S_4$SD. As well, weight of 1000-winnowed rough rice of side dressing method was numerically higher than uniform application method. SSC and FWC treatments applied by side dressing method were found significantly higher in weight of 1000-winnowed rough rice in comparison to control treatment CF (19.7 g) however, in comparison to control treatment NF they were smaller (23.6 g) except treatments $F_3$SD and $F_4$SD which were at par with NF (Table 3.11).

**Culm length (cm)**

Culm length was differ with different methods of application, different types of compost and the N levels (amount) of composts.

Within SSC treatments applied by uniform application method, the maximum culm length was depicted in treatment $S_4$ (88.2 cm) which was at par with treatments $S_3$ and $S_2$ (87.3 and 84.7 cm, respectively) however, the significantly minimum culm length was counted in treatment $S_1$ (75.9 cm). Meanwhile, culm length of FWC treatments $F_4$, $F_3$ and $F_2$

applied by uniform application method were found maximum and did not significantly differ with each other (85.4, 83.2 and 80.0 cm, respectively) but, treatment $F_1$ registered the significantly minimum (76.5 cm). Culm length of all SSC and FWC treatments applied by uniform application method were found significantly higher than treatment NF (61.4 cm) but they were smaller than control treatment CF (93.8 cm) except treatment $S_4$ which was at par with CF.

Within SSC and FWC treatments applied by side dressing method, culm length of SSC treatments ($S_1$SD, $S_2$SD, $S_3$SD and $S_4$SD) did not significantly differ with each other (84.5, 86.4, 88.5 and 89.7 cm, respectively). Among FWC treatments, culm length of treatments $F_2$SD, $F_3$SD and $F_4$SD were found at par with each other and significantly higher (81.7, 85.5 and 83.8 cm, respectively) than treatment $F_1$SD (76.2 cm). Culm length of SSC treatments performed better than FWC treatments. As well, culm length of side dressing method was numerically higher than uniform application method. Culm length of SSC and FWC treatments applied by side dressing method were found significantly higher than treatment NF (61.4 cm) however, control treatment CF was found significantly higher (93.8 g) than all SSC and FWC except treatments $S_3$SD and $S_4$SD which were at par with CF (Table 3.11).

**Panicle length (cm)**

Panicle length was differ with different methods of application, different types of compost and the N levels (amount) of composts.

With uniform application method, the significantly maximum panicle length of SSC treatments was registered in treatment $S_4$ (21.1 cm) which was at par with treatment $S_3$ (19.2 cm) and the significantly minimum was depicted in treatment $S_1$ (16.6 cm) which was at par with treatment $S_2$ (17.9 cm). Meanwhile, panicle length of FWC treatments $F_2$, $F_3$ and $F_4$ applied by uniform application method did not significantly differ with each other (19.7, 20.4 and 22.1 cm, respectively) however, the significantly shorter panicle length was recorded in treatment $F_1$ (16.9 cm). Control treatment CF (18.3 cm) was found significantly smaller than treatments $F_4$, $F_3$ and $S_4$; similar to treatments $F_2$, $S_3$ and $S_2$; and higher than treatments $S_1$, $F_1$ and NF (9.2 cm).

With side dressing method, within SSC treatments, panicle length of treatments $S_2$SD, $S_3$SD and $S_4$SD (19.7, 21.5 and 19.8 cm, respectively) were registered maximum ad similar with each other, but significantly higher than treatment $S_1$SD (17.7 cm). As well, within FWC treatments applied by side dressing method, panicle length was registered maximum with treatment $F_3$SD (20.5 cm) which was at par with treatments $F_2$SD and $F_4$SD (18.6 and 20.3 cm, respectively) and the significantly minimum was recorded in treatment $F_1$SD (16.7 cm). Control treatment CF (18.3 cm) was found significantly smaller than treatments $F_4$SD, $F_3$SD and $S_3$SD; similar to treatments $F_2$SD, $S_4$SD and $S_2$SD; and higher than treatments $S_1$SD, $F_1$SD and NF (9.2 cm) (Table 3.11).

**Percentage of productive culms (%)**

Percentage of productive culms was differ with different methods of application, different types of compost and their N levels (amount).

Within SSC treatments applied by uniform application method, treatment $S_3$ depicted the maximum percentage of productive culms (86.8) which was at par with treatments $S_4$ and $S_2$ (82.7 and 75.8, respectively) however, the significantly minimum percentage of productive culms was counted in treatment $S_1$ (64.0). Meanwhile, percentage of productive culms of

FWC treatments $F_4$, $F_3$ and $F_2$ applied by uniform application method were found maximum and did not significantly differ with each other (97.0, 92.3 and 81.3, respectively) but, treatment $F_1$ registered the significantly minimum (70.8). Percentage of productive culms of all SSC and FWC treatments applied by uniform application method were found significantly similar to control treatment CF (67.3) except treatments $F_4$ and $F_3$ which were higher than CF.

Within SSC treatments applied by side dressing method, percentage of productive culms of SSC treatments $S_2SD$, $S_3SD$ and $S_4SD$ were found higher and did not significantly differ with each other (76.9, 81.2 and 82.9, respectively) but the significantly lower was registered with treatment $S_1SD$ (64.2). As well, among FWC treatments applied by side dressing method, percentage of productive culms of treatments $F_2SD$, $F_3SD$ and $F_4SD$ were found at par with each other and significantly higher (78.6, 87.3 and 89.1, respectively) than treatment $F_1SD$ (62.9). Percentage of productive culms of FWC treatments performed better than SSC treatments. As well, percentage of productive culms of uniform application method was numerically higher than side dressing method. Percentage of productive culms of SSC and FWC treatments applied by side dressing method were found significantly higher than treatment NF (53.5) except treatments $S_1SD$ and treatment $F_1SD$ which were at par with NF. Percentage of productive culms of control treatment CF (67.3) was found similar to all SSC and FWC treatments applied by side dressing method except treatments $F_4SD$ and $F_3SD$ which were higher than CF (Table 3.11).

Table 3.12 shows the analysis of variance using the yield data of all treatments in 2017. In order to analyze effects of quality (types of compost), quantity (amount of compost) and methods of compost application on yield, yield data of compost treatments were subjected to four-way ANOVA. Subsequently, Tukey multiple comparisons were performed (Table 3.13).

Significant differences in yield were observed between two compost types (SSC and FWC), different amount (5.5, 11.0, 16.5 and 22.0 g N per pot) and methods of compost application ($P<0.05$). However, no significant difference was obtained between the blocks. As well, the interaction effects of different types of compost, amount of compost, application method and blocks (the sources of variation) were not found significant regarding the yield (Table 3.12).

Table 3.13 shows the Tukey multiple comparison test of yield, using the data of 2017. The yield was significantly differed by application of two kinds of compost, the yield of SSC (111.6 g per pot) was significantly greater than that of FWC (76.7 g per pot) ($P < 0.05$). Increase in the amount of compost (based on four N levels of the composts) resulted in a significant increase in yield. The amount of compost per pot which contained 5.5 g N produced significantly lower yield (64.5 g), followed by 11 g N (90.9 g), but the significantly high yield was found with 22 g N (111.6 g) which was at par with 16.5 g N per pot (109.7 g). However, no significant difference in yield was recorded with the amount of compost contained 11.0, 16.5 and 22 g N per pot. Side dressing method of both composts (SSC and FWC) produced significantly higher yield (98.9 g) than uniform application method (89.4 g). Uniform application of compost is common in rice production, but it caused inhibition effects at the early growth stage of rice plants, while the side dressing reduced this problem. There was no significant different on yield of different blocks (Table 3.13).

**Table 3.11 Yield character and components per hill in 2017.**

| Treatment | Top air-dry weight per hill (g) | Yield (winnowed rough rice) per hill (dry weight, g) | Number of productive panicles per hill | Average Number of spikelets per panicle | Percentage of ripened grains (%) | 1000-winnowed rough rice grain (dry weight, g) | Culm length (cm) | Panicle length (cm) | Maximum tiller number per hill | Percentage of productive culms (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **$S_1$** | 72.6 bcd | 29.6 cd | 25.8 c | 63.7 ab | 81.7 de | 22.1 cd | 75.9 b | 16.6 a | 40.5 c | 64.0 ab |
| **$S_2$** | 104.7 ef | 37.8 de | 36.2 d | 72.9 bc | 69.4 cd | 20.7 bc | 84.7 cd | 17.9 ab | 48.2 cd | 75.8 bc |
| **$S_3$** | 128.9 f | 42.7 e | 40.7 d | 83.8 d | 60.6 bc | 20.6 b | 87.3 d | 19.2 bc | 47.3 c | 86.8 cd |
| **$S_4$** | 127.7 f | 35.4 de | 37.3 d | 94.3 e | 48.5 b | 20.7 b | 88.2 de | 21.1 c | 46.0 c | 82.7 cd |
| **$F_1$** | 46.5 b | 19.7 b | 16.0 b | 70.3 bc | 81.8 de | 21.5 bcd | 76.5 b | 16.9 a | 23.0 ab | 70.8 bc |
| **$F_2$** | 65.8 bcd | 26.6 bcd | 20.0 b | 85.9 d | 72.9 cd | 21.1 bc | 80.0 bc | 19.7 bc | 25.0 ab | 81.3 cd |
| **$F_3$** | 79.9 cde | 34.1 cd | 22.3 b | 98.0 e | 71.2 cd | 22.0 cd | 83.2 c | 20.4 c | 24.5 ab | 92.3 d |
| **$F_4$** | 89.4 de | 36.6 de | 22.0 b | 111.8 f | 65.6 bcd | 22.8 de | 85.4 cd | 22.1 c | 23.2 ab | 97.0 d |
| **$S_1$ SD** | 84.6 de | 33.9 cd | 26.3 c | 69.3 bc | 84.5 de | 22.1 cd | 84.5 cd | 17.7 a | 41.5 c | 64.2 ab |
| **$S_2$ SD** | 112.0 f | 43.5 e | 35.8 d | 80.6 d | 72.8 cd | 20.7 bc | 86.4 d | 19.7 bc | 47.2 c | 76.9 bc |
| **$S_3$ SD** | 132.4 f | 48.2 e | 38.0 d | 84.7 d | 71.0 cd | 21.2 bc | 88.5 de | 21.5 c | 47.0 c | 81.2 cd |
| **$S_4$ SD** | 130.3 f | 42.7 e | 41.2 d | 85.4 d | 57.1 bc | 21.2 bc | 89.7 de | 19.8 bc | 49.8 cd | 82.9 cd |
| **$F_1$ SD** | 54.5 bc | 21.5 b | 18.3 b | 63.0 b | 85.2 e | 21.9 bcd | 76.2 b | 16.7 a | 29.7 b | 62.9 ab |
| **$F_2$ SD** | 81.2 de | 33.0 bcd | 25.8 c | 71.9 bc | 82.8 de | 21.5 bcd | 81.7 bc | 18.6 bc | 33.2 b | 78.6 bcd |
| **$F_3$ SD** | 97.6 e | 41.4 e | 26.8 c | 88.6 de | 78.2 de | 22.4 de | 85.5 cd | 20.5 c | 31.5 b | 87.3 d |
| **$F_4$ SD** | 98.9 e | 41.5 e | 29.7 c | 83.1 d | 75.3 de | 22.5 de | 83.8 cd | 20.3 c | 33.5 b | 89.1 d |
| **NF** | 25.9 a | 10.6 a | 9.2 a | 55.8 a | 88.5 e | 23.6 e | 61.4 a | 17.8 a | 17.2 a | 53.5 a |
| **CF** | 114.8 f | 23.7 bc | 40.0 d | 78.6 cd | 38.1 a | 19.7 a | 93.8 e | 18.3 b | 59.5 d | 67.3 bc |

Data represent mean (n=3). Means within each column with the same letter(s) are not significantly different at $P<0.05$, using Tukey multiple comparisons test.

**Table 3.12 ANOVA table of yield, using the data of 2017.**

| Source of variation | df | SS | MS | F-stastic | P-value | |
|---|---|---|---|---|---|---|
| Types (T) | 1 | 14635.5 | 14635.5 | 186.01 | P < 0.001 | ** |
| Amounts (A) | 3 | 17193.9 | 5731.3 | 72.84 | P < 0.001 | ** |
| Application methods (C) | 1 | 1080.2 | 1080.2 | 13.73 | 0.0100 | * |
| Blocks (B) | 2 | 7.4 | 3.7 | 0.05 | 0.9546 | |
| T x A | 3 | 284.1 | 94.7 | 1.20 | 0.3858 | |
| T x C | 1 | 116.7 | 116.7 | 1.48 | 0.2690 | |
| T x B | 2 | 88.2 | 44.1 | 0.56 | 0.5983 | |
| A x C | 3 | 50.0 | 16.7 | 0.21 | 0.8847 | |
| A x B | 6 | 361.7 | 60.3 | 0.77 | 0.6227 | |
| C x B | 2 | 281.7 | 140.8 | 1.79 | 0.2457 | |
| T x A x C | 3 | 129.4 | 43.1 | 0.55 | 0.6675 | |
| T x A x B | 6 | 515.2 | 85.9 | 1.09 | 0.4591 | |
| T x C x B | 2 | 48.9 | 24.4 | 0.31 | 0.7441 | |
| A x C x B | 6 | 481.4 | 80.2 | 1.02 | 0.4908 | |
| Error | 6 | 472.1 | 78.7 | | | |
| Total | 47 | 35746.3 | | | | |

** and * Significant at 0.01 and 0.05 level of probability, respectively.

**Table 3.13 Tukey multiple comparisons test of yield, using the data of 2017.**

| Source of variation | | Mean (g/pot) | |
|---|---|---|---|
| Types | SSC | 111.6 | b |
| | FWC | 76.7 | a |
| Amounts | 5.5 g T-N/pot | 64.5 | a |
| | 11.0 g T-N/pot | 90.9 | bc |
| | 16.5 g T-N/pot | 109.7 | c |
| | 22.0 g T-N/pot | 111.6 | c |
| Application methods | Side dressing | 98.9 | b |
| | Uniform | 89.4 | a |
| Blocks | B1 | 94.7 | a |
| | B2 | 94.1 | a |
| | B3 | 93.7 | a |

Means within each column of each source of variation with different letter(s) are significantly different at $P<0.05$.

## Discussion

The results of experiment have been presented in preceding topics. They are required to be discussed in the light of scientific knowledge and principles of Agronomy. Interpretations have been made in the view of the factors governing the manifestation of result and their corroboration light of results obtained by other scientist workers engaged in the relative field of research. The result of this study show significant effects regarding the different application method of SSC and FWC with their levels on growth and yield of rice plant. The growth parameters and yield components were differed by different method of compost application, different types of compost and their levels.

**Plant growth characters**

The decrease in tiller numbers at the early stage caused by increasing the levels of SSC and FWC application might be due to the rate of decomposition and the mineralization process of compost which cause immobilization of nutrient. The immobilization of nutrient especially nitrogen in all compost treated soils was reported by Vanlauwe *et al.* (1998) which most of the soil nitrogen was held in organic form. Based on visual observation, compost application by its microbial activities and decomposing process caused an abnormal condition in the soil by putrefying soil and water, changing their color, smell and temperature at the initial growth stage. This condition affected root development particularly initial roots, and rice plants which were sensitive at this stage could not uptake nutrients and grew properly. Therefore, the higher amount of compost (N level) applied produced the lower tiller number (Fig. 3.7, Fig. 3.8 and Table 3.6). Abe *et al*. (1995) reported that the application of castor meal two weeks before transplanting as basal dressing resulted in the dying off of most of the leaves and markedly inhibited root growth at seedling stage and the magnitude of the damage was depended on the amount of organic material applied.

The heavier inhibition effect of FWC than SSC at the early growth stage (Figs. 3.3-3.8 and Tables 3.4-3.6) might be due to microbial activity in soil, compost ingredients, method of composting and aromatic acid. FWC was prepared under aerobic conditions, by which it was situated in a water-flooded condition, FWC created undesirable satiation for plant growth. It was also described by Tanaka and Ono (2000) that decrease in the redox potential of soil following harmful metabolite production during soil microbial fermentation under anaerobic conditions. As well. Tanaka and Ono (2000) reported in a pot experiment with different organic matters that rice seedling growth was inhibited by application of the same organic matter that led to the accumulation of aromatic acids in the soil.

**Dry matter production and yield characters**

The decreases in the dry weight of root, leaf sheath, leaf blade and top by increasing N levels (amount) of SSC and FWC at the early growth stage are not only due to the unavailability of nutrients but also possibly a result of the microbiological activity of compost, enzyme activity and biomass-specific respiration in the soil. Albiach *et al.* (2000) reported that annual application of organic residues, municipal solid waste, bovine manure and sewage sludge, led to significant increase of soil enzyme activities. Zaman *et al.* (2002) reported in an experiment on different soil that the application of SSC increased microbial biomass and activities in the soil. Aoyama *et al.* (2006) described that the application of lime-treated SSC not only increased soil respiration but also biomass-specific respiration. Indeed, the rice root has $O_2$ releasing and oxidizing ability, but higher microbial biomass and respiration led to higher cumulative $CO_2$ in the soil which retarding the root growth and development. The low levels of both composts produced high root dry weight, and the treatments with high root dry weight recorded high top dry weight as well (Table 3.8). The growth and development of roots are assumed to mutually interact with the top. Osaki *et al*. (1997) also reported that high photosynthetic rate of shoots secures high root activity by supplying a sufficient amount of photosynthesis to the roots. Conversely, high root activity secures a high photosynthetic rate by supplying a sufficient amount of nutrients to shoot, so ensures high productivity.

Dry matter productions of side dressing of both composts (SSC/FWC) were higher and performed better than uniform application. Uniform application of compost is common in rice production, it caused inhibition effects at the early growth stage of rice plants while the side dressing method reduced that. It might be due to decreasing the negative effects of decomposition, mineralization and microbial activities of compost and increasing nutrient use efficiency which resulted in the higher T-R ratio (Table 3.8). Root growth and development of side dressing was better than that uniform application. According to visual observation, in the side dressing method, the roots of unapplied compost zone were grown and developed better than the roots of applied compost zone (Pictures 3.1 and 3.2). It can also prove form Table 3.8 that root dry weight of no fertilizer treatment (NF) is higher than compost applied treatments. It might be in consequence of the redox potential of soil too, the redox potential decreased by uniform application of FWC and SSC. Tanaka and Ono (2000) described that decrease in the redox potential of soil following harmful metabolite production. As well, Yang *et al*. (2004) described that when farmyard manure was incorporated to paddy soil with a continuously submerged condition, rhizosphere soil redox potential significantly decreased and simultaneously the concentration of extractable $Fe^{2+}$ enhanced, and such condition is potentially harmful to root health.

Panicle number and panicle length of $S_1$, $F_1$, $F_2$, $S_1$SD, $F_1$SD and $F_2$SD were recorded significantly lower than CF treatments but due to the higher percentage of ripened grain and 1000 winnowed rough rice grain weight, the yield of $S_1$, $F_1$, $F_2$, $S_1$SD, $F_1$SD, and $F_2$SD treatments were found at par with CF treatment. However, the rest of treatments obtained significantly higher yield than CF. In fact, these treatments produced higher average number of spikelets per panicle, percentage of ripened grain, 1000 winnowed rough rice grain weight and panicle length (Table 3.11).

From the viewpoint of types of compost, the contribution in yield of SSC was better than FWC. Since effects of SSC on yield was greater than FWC (Table 3.12). From the viewpoint of quantity of compost, the yield was increased by increasing the amount of compost, the amount of compost per pot which contained 5.5 g N produced significantly lower yield. However, the significantly high yield was found with 22.0 g N which was at par with 16.5 and 11.0 g N per pot (Table 3.13). According to the result of this study, side dressing method of compost application at the basal was found better than the uniform application because side dressing reduced the early growth inhibition (Figs. 3.3-3.8), produced more dry matter productions (Table 3.8) and yield (Table 3.11) than that of the uniform application.

The side dressing of compost is a technique that can reduce the inhibition effects of SSC and FWC application, especially for early transplanting of rice plant and increase rice yield at the end. On the other hand, the side dressing of FWC and SSC released nutrient slowly and this method increased the fertilizer use efficiency. For this technique, the transplanting machine needs to be equipped with a compost application unit to apply and mix compost in a line, at the depth of over 10 cm and 7-10 cm aside from the rice seedlings. Development of transplanting machine with compost application unit will save dressing labor cost as well.

**Conclusion**

In conclusion, the application of FWC and SSC had inhibiting effects on tiller number and dry matter production at the early growth stage of rice plants. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effects of FWC was heavier than that of SSC. However, SSC produced higher yield than FWC and side dressing than uniform application. The yield was increased by increasing the amount of compost, the amount of compost per pot which contained 11.0 g N produced significantly high yield and can be an alternative for chemical fertilizer. Side dressing method was found better than the uniform application. This method reduced the inhibition effects at the early growth stage, increased yield of rice plant, promoted nutrient use efficiency, and if the side dressing method develop in the transplanting machine it can reduce the labor dressing cost.

* * *

# Chapter Five

## Summary

Crop production uses the cyclical functions of nature. For sustainable agriculture, it is important to apply organic materials to soil as fertilizers and conditioner to enhance crop production. After the Food Waste Recycling Law of Japan (2000) was enacted, Food waste compost (FWC) and sewage sludge compost (SSC) emerged as new types of compost. These composts are mainly produced from cyclical food resources, such as food waste, food processing residues and sewage sludge from food factories, wood chips, and grass clippings. Composts made from food wastes and sewage sludge can be an important organic fertilizer in crop production from the viewpoint of containing N, phosphorus (P), potassium (K) and other plant nutrients, conserving resources and the environment and they are relatively cheap. SSC and FWC are thought to cause little environmental pollution, as they are controlled for the level of heavy metals and do not contain domestic animal excreta.

In the first study, we investigated the effects of SSC and FWC application with different nitrogen levels on the growth and yield of rice plants. The result showed obviously effects of application of SSC and FWC with their levels on plant growth parameters of rice. The early growth stage of rice plant was inhibited by application of SSC and FWC compared to chemical fertilizer (CF). The slower leaf emergence, fewer tiller numbers and short plant length were caused by SSC and FWC application and the growth inhibition increased by increasing the quantity of compost at the early growth stage while it was decreased at the late stage. The inhibition effect of FWC was more powerful than SSC. As well, high amount of compost resulted delayed heading stage and mature stage. The SPAD value of top three leaves at heading stage and 10 days after heading stage was also increased by increasing level

of SSC and FWC, even higher than CF treatment. In addition, significant difference was observed on yield component with application of SSC and FWC and their levels. Yield of standard level of chemical fertilizer (CF) which applied at the rate of 6.1 g nitrogen (N) per pot was observed 38.4 g per hill in 2015 and 44.8 g per hill in 2016. In comparison to the yield of SSC and FWC which their N levels varied between 5.5 – 22.0 g N per pot, the yield of CF was found higher than the low level of both composts (5.5 g N per pot). Yield of SSC and FWC separately, at the rate of 11.0 g N per pot were found 44.6 and 38.5 g per hill in 2015, and 45.0 and 32.4 g per hill in 2016, respectively. Yield of these composts at the rate of 16.5 g N per pot were found 52.8 and 52.0 g per hill in 2015, and 40.9 and 36.5 g per hill in 2016, respectively. Yield of SSC and FWC at the rate of 22.0 g N per pot were found 57.6 and 41.1 g per hill in 2015, and 40.7 and 25.1 g per hill in 2016, respectively. Therefore, it was thought that yield by fertilization of SSC at the rate of 11.0 g N per pot was similar to CF. From the view point of few depression and prevent delay of heading stage, treatments $S_2$ (at rate of 11.0 g N per pot) was found more effective and can be an alternative for chemical fertilizer.

To confirm the inhibition effects of SSC and FWC at the early growth stage it was planned to investigate and elucidate the effects of these composts on rice plants at different times of cultivation in the second study.

In the second study, it was confirmed from the results of five repetitions in two years that the basal application of FWC and SSC had inhibiting effects on growth parameters and dry matter production at the early growth stage of rice plants. The degree of inhibition was increased by increasing the levels of each compost. The inhibition effects of FWC were heavier than that SSC. Since this phenomenon on early growth stage in rice plant was seen five times in two year, it was thought to be a common characteristic of composts. The early transplanting of rice plants was inhibited at initial growth stage heavier than late transplanting, which was a severe problem that basal composts (SSC and FWC) application created.

In Japan, rice transplanting time has been starting earlier over the past 50 years, early-season cultivation of rice plant was carried out in Mie prefecture by using main cultivar Koshihikari. We expected from the results of first and second studies that if we could a mechanism to reduce the inhibition effects at the early growth stage of rice plant which caused by application of compost, we might be able to increase the yield of rice. Therefore, we believed that different methods of fertilizer application are options for solving the inhibition effects of SSC and FWC application at the early growth stage. With this method, we might promote the initial growth, save labour for fertilizer application, and increase fertilizer use efficiency. In the light of the above viewpoints, it was planned to investigate and find a way to solve the problem of inhibition effects of SSC and FWC application on rice plants at the early growth stage and improve rice yield.

In third study, it was clarified that the side dressing of compost is a technique that can reduce the inhibition effects of SSC and FWC application, especially for early transplanting of rice plant. The side dressing method was found better than the uniform application. This method reduced the inhibition effects at the early growth stage, increased yield of rice plant, promoted nutrient use efficiency, and if the side dressing method develops in the transplanting machine it can reduce the labor dressing cost.

This study clarified as follows:

1. New types of composts (SSC and FWC) were useful to rice cultivation as eco-friendly farming. Although, SSC performed better than FWC.

2. New Types of compost had inhibition effects at early growth and delayed heading stage, but they had useful effects on yield character at the end.

3. SSC and FWC at rat of 11 g N per pot can be a good alternative for CF.

4. The SSC and FWC application with early transplanting (transplanted on April 29) inhibited higher than late transplanting (transplanted on May 23 and June 3).

5. The side dressing method could alleviate the depression and delayed of heading stage which caused by basal application of SSC and FWC.

6. The side dressing method increased yield of rice plant and it was found better than the uniform application method.

* * *

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