BALANCED FERTILIZERS AND STRAW RESIDUE MANAGEMENT ON BLACK GRAM (*Vigna mungo* L. Hepper) GROWN AFTER RICE IN MAUBIN AND DAIK U TOWNSHIPS

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Soil and Water Science)

Department of Soil and Water Science
Yezin Agricultural University
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The thesis attached hereto, entitled **"Balanced Fertilizers and Straw Residue Management on Black gram (*Vigna mungo* L. Hepper) grown after Rice in Maubin and Daik U Townships"** was prepared under the direction of the chairman of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for the degree of **Master of Agricultural Science (Soil and Water Science).**

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DECLARATION OF ORIGINALITY

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

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DEDICATED TO MY BELOVED PARENTS

U KO LAY AND DAW TIN AYE

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ABSTRACT

To evaluate the effect of balanced fertilizers and straw residue management on the the changes of soil organic carbon and nitrogen, yield and agronomic components, total water use (WU) and water use efficiency (WUE) of black gram, the experiments were conducted at the fields of Maubin township (pH - 5.84, silty clay soil) and Daik U township (pH - 4.34, silt loam soil) in winter season, 2015 as a second crop after rice. The experiments were set up 2×5 factorial randomized complete block design with three replications involving without rice straw mulching (M_0) or with rice straw mulching (M_1) and balanced fertilizers methods. In this investigation, 3 ton ha^{-1} of rice straw was mulched and F_0= non-fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}, F_3= 14- 19- 32 NPK kg ha^{-1}, F_4= 14- 19- 32 NPK plus 0.025 ammonium molybdate kg ha^{-1} were applied as balanced fertilization. Based on the two strong investigations, changes of soil C in Maubin was varied from slightly decrease 9 % in M_0F_0 to significantly increase to 61 % in M_1F_3 whereas in Daik U was from greatly decrease 22 % in M_0F_4 to merely increase to 9 % in M_1F_3 and increment of soil nitrogen to 10 % under M_1F_3. In terms of N changes in Maubin township, balanced fertilizers application and rice straw mulching has a great influence on increment of soil nitrogen as 11% under M_1F_4 and it also produces the maximum seed yield (758.48 kg ha^{-1}) indicating the high performance of pod number $plant^{-1}$, seed number pod^{-1}, 100 seed weight, total dry matter, maximum WUE (5.02 kg ha^{-1} mm^{-1}) and higher water was used in without mulching treatments. However, in Daik U township, the best results showing maximum yield (1273.90 kg ha^{-1}) and its high agronomic performance were observed in M_1F_3. It also gave the maximum WUE (8.66 kg ha^{-1} mm). In addition, more soil moisture (28.72 and 16.23 mm) at the end of crop was stored under balanced fertilizer application with rice straw mulching in both regions. From this study, mulching with rice straw in black gram cultivation for both regions is the appropriate management practice for improving yield, water use efficiency and residual soil moisture whereas different balanced fertilizer recommendations could be applied for both.

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CHAPTER I
INTRODUCTION

Legumes have important roles in farming systems, reducing cereal diseases, providing weed management options and contributing significant nitrogen to rotations. Pulses, an important component of crop diversification particularly in areas with limited irrigation water to grow rice, are known to improve soil quality through their unique ability of biological N_2 fixation. Myanmar's pulses are usually grown during the summer season at the beginning of November making use of the residual moisture left in the soils after harvesting of paddy rice. Growing periods for pulses are about 3 to 4 months from sowing to harvest, and thus summer crops sown in November are usually harvested in January/February. Those crops planted at a later period during winter are usually harvested around February or March. Moreover, continuous cultivation of rice – rice cropping system is under threat with decline in soil organic carbon (SOC), total productivity and overall sustainability. From a point of views, pulses are major sources of proteins and complement the staple cereals in the diets with proteins, essential amino acids, vitamins and minerals. They contain 22 to 24% protein, which is almost twice the protein in wheat and thrice that of rice (Shukla et al. 2013).

Several intensive rice based cropping systems have been identified and are being practiced by the farmers. While intensive agriculture, involving exhaustive high yielding varieties of rice and other crops, has led to heavy withdrawal of nutrients from the soil, imbalanced and discriminate use of chemical fertilizers has resulted in deterioration of soil health (John et al. 2001). Intensive agriculture with very high nutrient turnover in soil-plant system coupled with low and imbalanced fertilizer use have resulted in deterioration of native soil fertility and created a serious threat to long-term sustainability of crop production (Kumar and Singh 2009). Inclusion of pulses vegetable in the cropping system is more beneficial than cereals after cereals (Kumpawat 2001). Generally, farmers use imbalanced chemical fertilizers for individual crop without considering cropping pattern for the whole year. As a result, a huge amount of fertilizers are being misused every year in crop cultivation (Noor et al. 2008). However, proper fertilization is essential to improve the productivity of black gram. It can meet its nitrogen requirements by symbiotic fixation of atmospheric nitrogen (Mir et al. 2013).

The inclusion of pulses in the rice-based system after seven cropping cycles improved the SOC content, being greater in surface soil (0 – 20 cm) and declining with soil depth (Ghosh et al. 2012). Pulse- based cropping systems are more suitable for resource-poor farmers and water scarce regions. The pulse-based cropping systems are environmentally sustainable also, since they require lower use of fertilizers, pesticides and irrigation in addition to enhancing the productivity of cropping systems by increasing yield of subsequent crops (Reddy 2004; Reddy 2009). In Myanmar, cultivation of pulses has increased substantially from 0.73 million hectare in 1988-89 to 5.91 million hectares in 2014 - 2015. Export of pulses increased from 17,000 metric tons in 1988-89 to 1.46 million metric tons in recent year. (MOAI 2015)

In Myanmar, total black gram sown area was 1,098,000 ha and total production was 1,580,000 metric tons in 2014 -15 (DAP 2015). Most of black gram areas lie in Ayeyarwaddy division followed by Bago division. In these regions, black gram is grown as a second crop in the post monsoon season with the residual soil moisture after monsoon rice. Most area of Ayeyarwaddy Division, farmers practice rice straws, left in the pulse fields to be maintained residual soil moisture. In a consideration for soil management, mulch acts as a protective cover placed over the soil to hold moisture, provide nutrients, moderate erosion, encourage seed germination and suppress weed development. Mulching and its skillful application can lead to improve soil organic matter contents and by improving other soil characteristics (Harris et al. 2004). A good mulching material with adequate supply of nutrients is essential for plants to attain maximum production. Yield increases have been attributed to the ability of mulch to decrease soil temperature, enhance nutrient availability and increase root growth (Haque et al. 2003).

In Myanmar especially under rain-fed rice growing area, most farmers usually cultivate black gram and green gram as a second crop without irrigation. However, farmers applied much pesticide and foliar application to improve their production. This was a challenge to study how much watering to their crop including pesticide and fertilizer.

The popularity of rice - black gram or rice - green gram cropping patterns can be partially explained by the lack of irrigation water during summer season or external input requirements of pulses. Also, in recent years, farmers preferred to grow legumes as a second crop instead of rice because limited irrigation water and due to the high market value. Farmers are not only aware of the role of legumes in enhancing soil fertility, but more importantly, it become a genuine cash crop. It can be hypothesized that rice -legume cropping patterns will likely continue to shape the rice agroecosystems of Myanmar. Therefore, the study was conducted the following objectives;

- to compare the changes of soil organic carbon and nitrogen with and without residue management,
- to determine the effect of balanced fertilizer management on yield and agronomic components of black gram, and
- to analyze the effect of soil residual moisture content on growth and yield of black gram.

CHAPTER II
LITERATURE REVIEW

2.1 Cultivation of Black Gram

2.1.1 Cropping system of black gram

Black gram plays an important role in sustaining soil fertility by fixing atmospheric nitrogen and improving soil physical properties. Plant growth and development of black gram are greatly influenced by various environmental factors such as temperature, light, water and nutrient availability (Rajam 1997). Under abiotic stress conditions, where variations of above factors affect plant growth and development adversely, resulting in a dramatic reduction of the crop yield. However, pulses in crop production will benefit N inputs and residue retention to the maintenance of soil organic matter (Shah et al. 2003) and additional irrigation to pulses production instead of growing on residual moisture or mulching with the previous crop residues will increase its yield (Kumar 2011). Among the cropping systems, rice – rice – black gram, onion – rice – black gram, groundnut – rice – black gram and rice – rice – green gram cropping systems significantly improved the soil available nitrogen status in the first, second, third and fourth year respectively. In addition, the fixation of atmospheric nitrogen by the leguminous crops might have contributed for the increased soil N status (Mongia et al. 1989). To meet the potential yield, soils in black gram cultivation should have neutral pH with loam or clay loam texture. Black gram is cultivated on a variety of soils, but well-drained loams are best for its cultivation. In scanty rainfall areas, heavy soils are preferred. Owing to its salt tolerance, it can be grown in moderate saline and alkaline soils. Black gram can be successfully grown in soil with pH 5 to 8 (Gangaiah 2016).

2.1.2 Climatic requirement of black gram

Black gram (*Vigna mungo* L.) being a legume, it enriches soil N content and has relatively a short life span (90 - 120 days). The optimum time for sowing gram is the middle of October. It helps to control the wilt disease. Early sown crop suffers from wilt due to high temperature at the sowing time. The optimum temperature is 28 - 30 ˚C. Rate of germination in laboratory test decline are slower at temperature lower than 25˚C and particularly slow below 14 - 15˚C (Raiso et al. 1976; Angus et al. 1981). The threshold temperature for emergence in the field is around 10.5 ˚C (Angus et al. 1983). Depending on soil and climate, the water requirement of black gram varies from 150 - 200 mm and the amount of annual rainfall requires 500 - 700 mm (Gangaiah 2016).

2.2 Nutrient Requirements of Pulses

Fertilizer is one of the most important factors that affect crop production. Fertilizer recommendation for soils and crops is a dynamic process (Rafiqul Hoque et al. 2004; Singh and Kumar 2009; Singh et al. 2013) and the management of fertilizers is crucially important and balanced to the requirement of crop as well as the soil implement because it greatly affects the growth, development and yield of pulses.

2.2.1 Importance of nitrogen in pulses

Mostly, nitrogen is useful for pulse crops as it is a major component of protein (BARC 2005). Although pulses can fix atmospheric N_2 by mean of symbiotic, application of the nitrogenous fertilizer as starter or initial dose becomes helpful in increasing the growth and yield of legume crops (Ardeshana et al. 1993). If the crop was not fertilized with N, yields that do not acquire N through symbiotic atmospheric N fixation (such as alfalfa and soybean) can be very limited. If no N (forms of chemical fertilizer or manure) is applied for many years, the ability of soils to supply available N for plant becomes depleted. In long - term research of Iowa was shown that corn yield will average only about 50 bu/acre for continuous corn and 100 bu/acre for corn following soybean (John Sawyer 2008). Amount of N fixed from the atmosphere by annual pulses are normally less than their requirements for growth (Cowell et al. 1989; Androsoff et al. 1995). In many cases, crops have a high N removal from harvested seed, which is similar to, or higher than the N they can fix. Consequently, the amount of N conserved in the soil for the following crop is usually small, even when the pulse crop straw is retained (Evans et al. 1989; Jensen 1989).

Nitrogen also takes part in chlorophyll synthesis and thus the process of photosynthesis and carbon dioxide assimilation (Jasso-Chaverria et al. 2005). N shortage within plant tissue results in reduction of foliage and roots expansion, loss in photosynthetic efficiency and disturbance of all metabolic functions (Marschner 1995). It constitutes about 1.5 - 6 % of the dry weight of many crops apart from being a constituent many organic compounds, nucleic acids and protein compounds (Sanjuan et al. 2003).

Nitrogen in soils occurs as organic and inorganic forms (Jones 2003) and plants absorb N mainly in the nitrate (NO_3^-) and ammonium (NH_4^+) forms, both of which are metabolized by plants. It stimulates vegetative growth resulting in large stems and leaves and also influences crop quality. Nitrogen also mediates the utilization of potassium, phosphorus and other elements in plants and the optimum amounts of these elements in the soil cannot be utilized efficiency if nitrogen is deficient in plants (Brandy 1984). Under nitrogen deficiency, plants exhibits stunted growth and small leaves while excess nitrogen results in lush plants with soft tissue and lateness in maturity (Wolf 1999). Limitation of nitrogen in any phase of the plant growth, causes reduction in yield. On the other hand, N fertilization had a positive and significant effect on seed yield, seed weight, number of pods per plant and number of seeds per plant (Abdzad Gohari and Amiri 2010)

2.2.2 Importance of phosphorus in pulses

Phosphorus is the second most important macronutrient limiting plant growth after nitrogen in most soils. It is a plant nutrient that intervenes in cellular energy transfer, photosynthesis and respiration and is a component of nucleic acid nucleotides, phospholipids and phosphorylated sugars (Marschner 1996; Plaxton and Carswell1999). Unfortunately, P is one of the least accessible nutrients in most soil especially under tropical conditions where low P availability is a big challenge to agricultural production (Kochian et al. 2004). Khan et al. (1999) reported that phosphorus application significantly increased the yield of mungbean. Many other researchers also reported that grain yield of legumes increased with increasing P_2O_5 up to 50 kg ha^{-1} (Thakuria and Saharia 1990; Patel and Patel 1991; Rajkhowa et al. 1992; Chovatia et al. 1993).

Black gram (*Vigna mungo* L.) being legume crop responds well to phosphorus application. Phosphorus is the major essential nutrient required by the crop. In legumes, nitrogen requirement is less as compared to phosphorus because major protein is supplied through nitrogen fixation. Therefore, phosphorus is a key nutrient for increasing productivity of pulses in general and black gram in particular. Legumes as such have a relatively high phosphorus requirement being utilized by plant and bacteria. (Rangar et al. 2012). Although the total amount of P is high in soils, available P for plant growth is often limited, especially in acid soils, where P is easily fixed by soil components into unavailable forms. Low P availability is a major limiting constraint for crop production on acid soils (Condel et al. 2014).

Plants require adequate P from very early stages of growth for optimum crop production (Grant et al. 2001). Restricted early-season P supply frequently limits crop production, and P fertilizer is commonly applied to ensure that sufficient P is available to optimize crop yield and maturity. Total soil P usually ranges from 100 to 2000 mg P kg^{-1} soil representing approximately 350 to 7000 kg P ha^{-1} in the surface 25 cm of the soil, although only a small portion of this P is immediately available for crop uptake

(Morel 2002). Crop removal may range from 3 to 30 kg P ha^{-1}, therefore crop production will gradually deplete available soil P in the absence of P application. The importance of adequate tissue P concentrations during early-season growth has been reported in many different crop species (Grant et al. 2001).

As P is a constituent of nucleic acids, phospholipids and ATP (Marschner 2012), its role is important in the cell division, flowering, fruiting including seed formation, crop maturation, root development and nodule. The enhanced root development and nodulation improves the supply of nutrients and water to the growing parts of the plants resulting in an increased photosynthetic area and thereby more dry matter production in chickpea (Parihar and Tripathi 1989).

Even though addition of P fertilizer increases grain yield in many crops such as common bean (Kassa et al. 2014), soybean (Devi et al. 2012) and the application of excess P fertilizer has been associated with environmental pollution (Marschner 2012). Phosphorus is critical to cowpea yield because it is reported to stimulate growth, initiate nodule formation as well as influence the efficiency of the rhizobium-legume symbiosis (Haruna and Aliyu 2011).

Soil P-deficiencies especially in tropical soils primarily result from either inherent low levels of soil P or depletion of P through cultivation. As legumes are phosphorus loving plants, they require phosphorus for growth and seed development and most especially in nitrogen fixation which is an energy-driving process (Sanginga et al. 2000). For seed development, P is also a component of phytin, a major storage form of P in seeds. An inadequate supply of P can reduce seed size, seed number, and viability.

2.2.3 Importance of potassium in pulses

Potassium (K) application has been neglected in many developing countries, including India, which has resulted in soil K depletion in agricultural ecosystems and a decline in crop yields (Regmi et al. 2002; Panaullah et al. 2006). Higher yields and crop quality can be obtained at optimal N : K nutritional ratios. K is an essential macronutrient required for proper development of plants. In addition to activation of numerous enzymes, K plays an important role in the maintenance of electrical potential gradients across cell membranes and the generation of turgor. It is also essential for photosynthesis, protein synthesis and regulation of stomatal movement and is the major cation in the maintenance of cation-anion balances (Marschner 1995). In addition, leaf K content was adversely affected by presence of higher concentrations of Al in the soil solution (Sivasubramanian and Talibudeen 1971). Its adequate supply during growth period improves the water relations of plant and photosynthesis (Garg et al. 2005); helps in osmotic-regulation of plant cell; assists in opening and closing of stomata (Yang et al. 2004); activates more than 60 enzymes (Bukhsh et al. 2011); synthesizes the protein, creates resistance against the pest attack and diseases (Arif et al. 2008); and enhances the mungbean yield (Ali et al. 2010).

Potassium is essential in maintenance of osmotic potential and water uptake and had a positive impact on stomatal closure which increases tolerance to water stress (Epstein 1972); enhancement of water use efficiency (Nguyen et al. 2002) and adjustment for low water potential under drought stress (Bukhsh et al. 2012). Thus, under drought conditions, the accumulation of potassium increases in plant tissues that improves uptake of water from soil to plants. Plants depend upon K to regulate the opening and closing of stomata. As K moves into the guard cells around the stomata, the cells accumulate water and swell, causing the pores to open and allowing gases to move freely in and out. If water supply is short, K is pumped out of the guard cells. The pores close tightly to prevent loss of water and minimize drought stress to the plant (Thomas and Thomas 2009).

The role of K in photosynthesis is complex. The activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production is probably more important in regulating the rate of photosynthesis than is the role of K in stomatal activity. When the sun’s energy is used to combine CO_2 and water to form sugars, the initial high-energy product is ATP. The ATP is then used as the energy source for many other chemical reactions. The electrical charge balance at the site of ATP production is maintained with K ions. When plants are K deficient, the rate of photosynthesis and the rate of ATP production are reduced, and all of the processes dependent on ATP are slowed down. The plant’s transport system uses energy in the form of ATP. Potassium is required for every major step of protein synthesis. The “reading” of the genetic code in plant cells to produce proteins and enzymes that regulate all growth processes would be impossible without adequate K (Patil 2011).

Potassium plays significant roles in enhancing crop quality. High levels of available K improve the physical quality, disease resistance, and shelf-life of fruits and vegetables used for human consumption and the feeding value of grain and forage crops. Quality can also be affected in the field before harvesting such as when K reduces lodging of grains or enhances winter hardiness of many crops. Pulse crops showed yield benefits from potassium application. Improved potassium supply also enhances biological nitrogen fixation and protein content of pulse grains (Srinivasarao et al. 2003).

Soil fertility was improved significantly with farmyard manure used either alone or in combination with NPK over that of initial soil status (Singh et al. 2001). The supply of phosphorus and potassium to leguminous crops is necessary especially at the flowering and pod setting stages (Zahran et al. 1998). Intensive crop production in combination with unbalanced fertilization has already resulted in depletion of soil K across large areas of China (Yang et al. 2004). Deficiency of K in crop production usually appears following increases in N and P fertilizer applications and neglect of K fertilization (Ju et al. 2005). Balancing the N, P and K ratio by increasing the input of K fertilizers is a practical way to increase N agronomic efficiency and to minimize the environmental impacts of N fertilization (Zhu and Chen 2002).

2.2.4 Importance of molybdenum in pulses

Molybdenum (Mo) is a trace element found in the soil and is required for the growth of most biological organisms including plants (Purvis 1955; Agarwala et al. 1978; Graham and Stangoulis 2005). Total Mo content of soil varies from 0.01 to 17.0 mg/kg (Kabata-Pendias 2011). Most agricultural soils contain a relatively low amount of molybdenum by comparison, with an average of 2.0 mg/kg total molybdenum and 0.2 mg/kg available molybdenum (Mengel and Kirkby 2001). The availability of molybdenum for plant growth is strongly dependent on the soil pH, concentration of adsorbing oxides (e.g. Fe oxides), extent of water drainage, and organic compounds found in the soil colloids. Molybdenum is essential for most organisms and occurs in more than 60 enzymes catalyzing diverse oxidation-reduction reactions in plant metabolism (Zimmer and Mendel 1999). The critical deficiency concentration in most crop plants is quite low, normally between 0.1 and 1.0 mg Mo/kg dry tissue (Gupta and Lipsett 1981). Because molybdenum is very mobile within the plant, its deficiency can be observed in the whole plant, most often in the middle of the plant or on old leaves by getting yellow or yellow-green colour (Hamlin 2007). Mo-deficient plants exhibit poor growth and low contents of chlorophyll and ascorbic acid (Marschner 1995; Liu 2002).

Generally, molybdenum is an essential micronutrient for plants and bacteria (Williams and Fraustoda Silva 2002). The function of Mo is closely related to plant nitrogen metabolism, and Mo deficiency is manifested as deficiency of plant N (Pollock et al. 2002). Many research explored as the effectiveness of Mo in different application fields. Brkic et al. 2004 also stated that the application of molybdenum stimulated nodulation and biological nitrogen fixation, thus increasing the legume yield. Moreover, (Katyal and Randhawa 1983) indicated that Mo is required in the synthesis of ascorbic acid is implicated in making iron physiologically available. In the description of Nautiyal et al. (2005), leguminous plants are very sensitive to molybdenum effects, but excess molybdenum may impair growth and decrease the seed yield of the crops. Furthermore, (Mendel and Hansch 2002; Williams and Silva 2002) discussed that similar to other metals required for plant growth, molybdenum has been utilized by specific plant enzymes as a co-factor that participate in reduction and oxidative reactions in plants.

Adsorption of Mo is positively correlated with the content of Fe and Al oxides and negatively correlated with organic-matter content Gupta (2007). Plant uptake of Mo is usually enhanced by the presence of soluble phosphorus (P) and decreased by the presence of available sulfur (S). In view of negative effects of sulfate on Mo uptake, application of triple super phosphate is clearly superior to the use of single super phosphate for Mo-deficient soils. Soil application of triple super phosphate (TSP) enhanced Mo uptake (Rebagfka et al. 1993).

2.3 Impact of Crop Residues Management on Soil Quality

Crop residues, in general, are parts of the plants left in the field after crops have been harvested and thrashed or left after pastures are grazed. Lal (1995) pointed the importance role of crop residues in the United States. An annual crop residues produced by 19 principal crops are estimated as 400 million tons year^{-1}, compared with 2962 million tons year^{-1} produced in the world. It means that the total amount of principal nutrients in crop residues ranges from 40 to 100 kg tons^{-1}. Major nutrients (N + P + K) contained in crop residues amount to 9 million tons year^{-1} in the United States and 74 million tons year^{-1} in the world. Crop residues can be used for improving soil health and productivity and are a major source of lignocelluloses entering the soil (Kumar and Goh 2000). However, its effectiveness varies with many factors affecting the crop residues quality, edaphic factors from the surrounding and methodological problems concerned with quality of crop residues characterization.

In Myanmar, rice straw is always available in the farmer’s field and when this indigenous material is used as mulch, it enhances vegetative growth by reducing soil moisture depletion and temperature (Kuo and Tsay 1981). About 25 % of nitrogen (N) and phosphorus (P), 50 % of sulphur (S) and 75 % of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient sources (Sidhu et al. 2007) estimated the quantity of nutrients available in rice and the paddy straw has 39 kg N/ha, 6 kg P/ha, 140 kg K/ ha and 11 kg S /ha. Incorporation of crop residues into soil or retention on the surface has several positive influences on physical, chemical and biological properties of soil. These practices increase hydraulic conductivity and reduce bulk density of soil by modifying soil structure and aggregate stability (Gupta et al. 2012). Addition of rice straw as mulch increases the C:N ratio, which influences the balance between mineralization and immobilization of nitrogen. Therefore, with rice straw as mulch on the soil surface, it is possible that surface applied N will be immobilized (Janssen 1996). The mulch also retains the broadcasted fertilizer granules and ammonia volatilization losses can be enhanced (Bacon et al. 1986). Rice straw application also increases the efficiency of chemical fertilizers in both temperate and tropical countries (Ponnamperuma 1984).

2.3.1 Soil physical properties

Crop residues play an important role in maintaining good soil physical conditions. In most climates, the removal of all crop residues from the field leads to a deterioration of soil physical properties (Kladivko 1994).

2.3.1.1 Soil erosion

The presence of crop residues on the soil surface is known to reduce both wind and water erosion of soil either directly by affecting the physical force involved in erosion or indirectly by modifying the soil structure through the addition of organic matter (Brown et al. 1989, 1996; Lafond et al. 1996).

Flat residues as a mulch on the soil surface act as a barrier restricting soil particle emission from the soil surface and also increasing the threshold wind speeds for detaching these particles. It has been reported that standing residues are more effective than flat residues in reducing erosion by reducing the soil surface friction velocity of wind and intercepting the slating soil particles (Hagen 1996). The greater the amount of residues left on the surface, the greater the reduction in wind erosion (Michels et al. 1995).

Many studies reported that incorporating residues to various degrees can reduce runoff and hence water erosion losses of soil by 27- 90% (Freebairn and Boughton 1985; Fawcett 1995). However, these reductions mainly occur where considerable amounts of residues remain on the soil surface after incomplete incorporation (Freebairn and Boughton 1985; Mc Gregor et al. 1990; Dormaar and Carefoot 1996).

2.3.1.2 Soil aggregation and soil structure

Information on the effect of crop residue management on soil aggregation is limited, although it is well established that OM helps maintain aggregate stability (Tisdall and Oades 1982; Haynes and Francis 1993). The addition of crop residues is expected to have a positive effect on soil structure and aggregation (Freebairn and Gupta 1990).

Nuttall et al. (1986) reported over a period of 6 years in the Canadian prairies that aggregates >0.84 and < 12.7 mm in size were most abundant with crop residues chopped and spread and were least abundant with autumn (fall) ploughing. Values for spring burning of crop residues were intermediate. However, other residue management treatments (removal, incorporation, twice the amount incorporated and burning) did not significantly affect aggregation in a 14-year study at Kansas (Skidmore et al. 1986).

An increase in geometric mean diameter (GMD) of aggregates has been observed within a week when small amounts of residue were added due to a flush of fungal growth, but when a large amount of residue was added, the increase in GMD was observed after only 6 weeks (Hadas et al. 1994).

2.3.1.3 Compaction and bulk density

The effect of residue management and tillage has been found to be variable. Some workers reported no effect (Blevins et at. 1977; Ismail et al. 1995) whereas others found lower soil bulk densities in a conservation tillage residue management system (Edwards et al. 1992), residue incorporation (Sidhu and Sur 1993), and no-tillage surface residue (Dao1996). Bulk density has been observed to be higher in conservation tillage and no-tilling residue fields, as soils continually consolidated in the absence of tillage or with shallow tillage (Voorhees and Lindstrom 1983; Unger 1986).

In most studies, increases in soil bulk density and compaction were reported in crops that were seeded in comparatively wide rows (0.7 to 1.0 m), such as corn (Vyn and Raimbault 1993), soybean (Fahad et al. 1987), or sorghum (Bruce et al. 1990) crops.

2.3.1.4 Soil hydraulic conductivity and infiltration

Crop residues increase soil hydraulic conductivity and infiltration by modifying mainly soil structure, proportion of macro-pores, and aggregate stability. These increases have been reported in treatments where crop residues were retained on the soil surface or incorporated by conservation tillage (Murphy et al. 1993). Up to eight fold increases in hydraulic conductivity in zero-tillage stubble retained have been reported over treatments where stubble was removed by burning (Bissett and O'Leary 1996; Valzano et al. 1997). Hydraulic conductivity under straw-retained direct drilled treatments was 4.1 times greater than that of straw-burnt conventional tillage treatments (Chan and Heenan 1993).

2.3.1.5 Soil moisture content

It has been well established that increasing amounts of crop residues on the soil surface reduce the evaporation rate (Bussiere and Cellier 1994; Prihar et al. 1996). Thus, residue-covered soils tend to have a greater moisture content than bare soils except after extended drought (Thomas et al.1990; Peterson et al. 1996). Studies have shown that soils retained more moisture when residues were retained on the soil surface by conservation tillage as compared to residue incorporation, removal, or burning (Unger 1986; Dormaar and Care foot 1996). Boyer and Miller (1994) reported at 27 and 18% decrease in surface and subsurface soil water-holding capacities, respectively, in burned treatments as compared to non burn. The amount of residue cover is also important in determining the moisture retention in soil (Power et al. 1986; Wilhelm et al. 1986).

2.3.2 Soil chemical properties

2.3.2.1 Soil pH

Soil pH is one of the most important factors influencing residue decomposition as it affects both the nature and size of population of microorganisms and the multiplicity of enzymes at the microbial level, which subsequently affect decomposition (Paul and Clark 1989). In general, the decomposition of crop residues proceeds more rapidly in neutral than in acid soils. Consequently, liming acid soils accelerate the decay of plant tissues, simple carbonaceous compounds, and SOM (Alexander 1977; Condron et al. 1993). Under field conditions in the United Kingdom, Jenkinson (1977) reported that 42% of the ryegrass-derived C still remained after 1 year in a soil of pH 3.7, whereas only 31 % remained in soils of pH between 4.4 and 6.9. This may be due to alterations in soil microbial populations and activity as soil pH changes. Characteristically, the population shifts from bacteria to actinomycete to fungi as soil pH declines (Alexander 1980). Therefore, the retention of crop residues is important for the redistribution of alkalinity or acidity within soils.

Few studies have investigated the direct effect of residues on soil pH change in the field. The contribution of residues to changes in soil pH is often confounded by other components of the soil-plant system. A number of long-term field trials have observed soil acidification where residues have been retained (Xu et al. 2002), which was largely due to high soil N status. In fact, burning (Heenan and Taylor 1995) and removal (Xu et al. 2002) of stubble reduced acidification, indicating that the stubbles were enhancing mineralization and N supply from other sources.

In most cases, residues would not be expected to cause net acidification. Poss et al. (1995) showed that alkalinity generated by wheat residues in the surface soil was simply alkalinity removed from the soil during plant growth. Nevertheless, residues with high N content (low C: N) are likely to cause acidification during later stages of decomposition. However, even for lucerne hay, Evans et al. (1998) showed that alkalinity generated was proportional to acidification caused by nitrification and nitrate leaching. It is inherently difficult to assess the direct biochemical effects of residues on soil pH from agronomic or management processes. Soil pH change by residues will depend on the relative contribution of alkalinity-producing or consuming processes and the depth at which they occur.

2.3.2.2 Soil organic matter and nitrogen

The addition of crop residues on OM and N increases may depend on the amount of residue added, quality of the residue environment, and the duration of addition. Short-term addition in hot climates, promoting rapid decomposition, may lead to only a slight or no increase in soil OM (Aggarwal et al. 1997), but long-term addition has been shown to increase both C and N contents (Karlen et al. 1994). The effect of crop residues on SOM content is related strongly to the amount of residues added and only weakly related to the type of residue applied (Rasmussen and Collins 1991). Earlier studies in the United States (Larson et al. 1972), Canada (Sowden 1968), and Germany (Sauerbeck 1982) concluded that different types of crop residues had similar effects on SOM and that it is more a function of microbial product recalcitrance than initial residue composition (Voroney et al. 1989).

Several studies showed that organic C and N in soil responded linearly to an increased rate of residue addition (Black 1973; Rasmussen et al. 1980). Soil C and N were found to decrease with time for all residue additions except manure, and the rate of decrease was related to the level but not the type of residue returned to the soil (Rasmussen and Collins 1991). Losses of OM will continue in many of the present cropping systems without adequate amounts of residue return to soil. While residue input may increase OM content, continued input must be sustained (Rasmussen and Collins 1991) as some long-term studies have shown that OM and N increased compared to removal or burning (Karlen et al. 1994).

2.3.2.3 The ratio of soil organic carbon and total nitrogen

Carbon (C) to nitrogen (N) ratio, (C/N) is an indicator of net N mineralization and accumulation in soils. Organic matter rich in carbon provides a large source of energy to soil microorganisms. Consequently, it brings population expansion of microorganism and higher consumption of mineralized N. Dense populations of microorganisms inhibit the upper soil surface and have an access to the soil N sources. If the ratio of the substrate is high there will be no net mineralization and accumulation of N (Attiwill and Leeper 1987). They further noted that as decomposition proceeds, carbon is released as CO_2 and the C/N ratio of the substrate falls. Conversion of carbon in crop residue and other organic materials applied to the soil into humus requires nutrients (Lal 2001). Plant residues with C/N ratios of 20:1 or narrower have sufficient N to supply the decomposing microorganisms and also to release N for plant use. Residues with C/N ratios of 20:1 to 30:1 supply sufficient N for decomposition but not enough to result in much release of N for plant use the first few weeks after incorporation. Residues with C/N ratios wider than 30:1 decompose slowly because they lack sufficient N for the microorganisms to use for increasing their number, which causes microbes to use N already available in the soil (Miller and Gardiner 2001). They have further stated that the wider the C/N ratio of organic materials applied, the more is the need for applying N as a fertilizer to convert biomass into humus. The most important soil chemical property affected by SOC is the cation exchange capacity (CEC) (FAO 1998), a very important index of soil fertility. Based on a survey of several different soils in the sub-Saharan Africa, Asadu et al. (1997) specifically indicated that SOM content could account for about 60% of the effective CEC of the soils.

2.3.2.4 Phosphorus

Stratification of P resulting from minimum tillage is believed to result in improved P availability because there is less soil contact of organic P in crop residues and hence less P fixation (Blevins et al. 1983). Burning cereal residues also resulted in a higher extractable P content in the surface 0 to 2.5 cm soil layer (Nuttall et al. 1986) and increased plant uptake (Van Reuler and Janssen 1996). Compared to residue removal, the incorporation of residues of cluster bean, mungbean, and pearlmillet has been found to increase available P, probably due to an increase in phosphatase (both acid and alkaline) enzyme activity (Aggarwal et al. 1997).

2.3.2.5 Other nutrients

Most studies on plant decomposition have focused on N dynamics, with little or no emphasis on other nutrients that are important in describing the crop response to decomposing organic residues on soils with marginal fertility. Even if residue decomposes quickly, nutrients contained in it are not subjected to the same rapid loss as that which occurred under burning (Luna-Orea et al. 1996). Instead, nutrients are released over time by chemical, physical, and biological processes. Considerable quantities are released within a short period of time depending on the residue quality (Luna-Orea et al. 1996) and the kind of nutrients (Lefroy et al. 1995). Increases in exchangeable cations (K, Ca, Mg) and base saturation have been reported (Geiger et al. 1992).

The greater availability of both macro-and micronutrients has been reported more under conservation tillage than other conventional tillage (Hargrove 1985; Edwards et al. 1992). The burning of crop residue has also resulted in an increased K content in the surface soil compared with no burning, crop residue removal, or incorporation (Moss and Cotterill 1985). Although burning induces short-term increases in nutrients, losses of nutrients due to burning can occur.

2.4 Influence of Soil pH and Soil Nutrient Availability

Theoretically, it was stated that less available for plant uptake in most tropical soils mainly because of its fixation with Ca in alkaline soils and Fe and Al in acidic soils. Although the total amount of P is high in soils, available P for plant growth is often limited, especially in acid soils, where P is easily fixed by soil components into unavailable forms. Low P availability is a major limiting constraint for crop production on acid soils (Condel et al. 2014). Application of fertilizer P increases the P concentration in the soil solution and the amount of adsorbed P and the quantity of P precipitated as secondary minerals. The nature of the precipitates depends on the predominance of Ca, Fe or Al ions and thus the pH-value of the soil (Sample et al. 1980).

Kilmer et al. (1968) showed that soil pH influenced on K availability. In addition, there was a marked increase in K fixation in soil where pH was elevated to about 9 or 10 with sodium carbonate. At pH values up to 2.5 there was essentially no fixation; between pH 2.5 and 5.5, the amount of K fixation increased very rapidly. Above pH 5.5, the amount of fixation increased slowly. Liming to very acid soil to pH of 6 would increase K uptake by plants.

Proper soil pH is an essential input for pulse production. Soil pH in the range of 6.2 to 6.8 is assumed to be optimum for the crop. The range may be slightly higher or lower on specific soil types. Situation of low pH are a much more common problem than situations with a high pH, although the latter problem exists on certain high lime soils. The addition of lime to soils where the pH is below the optimum range has several beneficial effects; nutrient availability is increased; there is reduced risk of toxicity from manganese and aluminum; nodulation and nitrogen fixation are increased; and in many soil the tilt is improved. The most common problem associated with low pH is molybdenum deficiency. Molybdenum availability is often increased by adding lime to raise the pH of the plow layer; however, soils with low total Mo content may require addition of fertilizer Mo even after the soil pH has been adjusted for optimum plant growth (Flemming 1980). Reisenauer et al. (1962) reported that Mo adsorption increased with decreasing pH 7.75 to 4.45. Vlek and Lindsay (1977) examined the solubility of Mo solid phases in soils with pH values ranging from 5.5 to 7.7. At high pH levels, depending upon soil type, iron, zinc, manganese or copper may become deficient. In low pH soils, toxic amounts of exchangeable Al^{3+} and Mn^{2+} create an unfavorable root environment for nutrient uptake. As a consequence, greater amount of K^{+} cannot readily be available (Havlin et al. 1999).

2.5 Mulching as a mean of Crop Residue Management

Mulching, one of the crop residue management, is a good cultural practice for the favorable manipulation of microclimate. The role of mulching on the growth and production of plant is well recognized. Mulching in the semi-arid tropic has been suggested to conserve soil moisture (Agarwal. 1996), decrease soil temperature, decrease runoff and soil erosion and sometimes even substitutes the soil. It protects the plants from loss of soil moisture by wind and soil evaporation and reduces the irrigation requirements. Mulches help check weed growth and improve the soil structure and fertility by trapping nutrient-rich, wind-borne dust (Gajri et al. 1994). Irrigation requirements are reduced and water storage efficiency was increased up to 66-80 percent by the use of straw mulch (Greb et al. 1970).

Mulches economizes use of N fertilizer, lessen the need of organic fertilizer and saves labor cost. Mulching-induced improvements in yield have often been ascribed to increased soil moisture (Baten et al. 1995). In addition, yield increases have been attributed to the ability of mulch to decrease soil temperature, enhance nutrient availability and increase root growth (Shahidul Haque et al. 2003).

A good mulching material with adequate supply of nutrients is essential for plants to attain maximum production. Straw mulching had different soil thermal properties under diverse temperatures from that of exposed soil; colder weather had higher soil temperatures under straw mulching than in non-mulched soils and lesser during hot weather (Bristow 1988; Fabrizzi et al. 2005; Sarkar et al. 2007). Mulching is beneficial to improve soil physical, biological and chemical conditions for better crop performance (Al-Rawahy et al. 2011; Christopher et al. 2011).

Mulches play an important role in nutrient uptake as they provide favorable environment for better root growth by increasing the soil temperature and conserving suitable soil moisture regime. The effective use of nutrients in mulch could be attained because of vigorous root system (Younis et al. 2010). Relatively better moisture and thermal regimes enhances root growth which ultimately leads to increase in the potential for efficient nutrient uptake (Kumar and Dey 2011). The precipitation takes enormous quantity of phosphorous used as nourishment into the soil's immobile pools and plants are unable to use this (Hao et al. 2002; Badawi 2010). Application of mulches reduces the loss of phosphorous by limited precipitation so it may lead to better and quality flowering. Retention of crop residues on the soil surface slows the runoff by acting as tiny dams, reduces surface crust formation and enhances infiltration (Gupta et al. 2012).

Mulching helps to maintain uniform temperature, controls weed and the draining of fertilizers, conserves soil moisture and improves irrigation efficiency (AVRDC 1990; Benoit and Ceustermans 1996). Moisture distribution in the upper soil layer is more uniform in comparison with non-mulched soil and more roots developed in that layer which usually has richer nutrients and useful microorganisms (Knavel and Mohr 1967; Lippert et al. 1964). The effect of surface mulch is almost always predictable. Surface mulch has been reported to have positive effect on the soil hydrothermal regime and crop yield (Thiagalingam et al. 1996). Mulches had a significant positive effect on plant height and the effect was more pronounced in lower water regime treatment than higher water regime treatment.

Mulches had a greater effect on tomato yield when compared to the corresponding levels of drip irrigation without mulch (Biswas et al.2015). Larbi et al. (2002) observed that grain yield in maize improved significantly with an increasing amount of crop residues applied as mulch. Larbi et al. (2002) also reported that soil organic carbon, total nitrogen and available soil phosphorus contents increased by crop residue amendments. A positive effect of mulching in combination with mineral fertilizer on millet yield in the Sahel has also been reported by Bationo et al. (1993) and Yamoah et al. (2002).

2.6.1 Water use efficiency (WUE)

Crop physiologists defined water use efficiency as the amount of carbon assimilated and crop yield per unit of transpiration (Viets 1962) and then later as the amount of biomass or marketable yield per unit of evapotranspiration. Crop scientists express and measure water use efficiency as the ratio of total biomass or grain yield to water supply or evapotranspiration or transpiration on a daily or seasonal basis (Sinclair et al. 1984). Biomass yield versus evapotranspiration relations have intercepts on the evapotranspiration axis, which are taken to represent direct evaporation from the soil (Hanks 1974), and yield can be considered a linear function of transpiration, provided water use efficiency does not vary greatly during the season.

The basic expression of agricultural water productivity is a measure of output of a given system in relation to the water it consumes, and may be measured for the whole system or parts of it, defined in time and space (Cook et al. 2006).

Irrigation scientists and engineers have used the term water (irrigation) use efficiency to describe how effectively water is delivered to crops and to indicate the amount of water wasted at plot, farm, command, or system level and defined it as the ratio of irrigation water transpired by the crops of an irrigation farm or project during their growth period to the water diverted from a river or other natural source into the farm or project canal or canals during the same period of time (Sharma et al. 2015).

2.6.2 Water supply and fertilization

Water supply can increase fertilizer use efficiency by increasing the availability of applied nutrients, and water and nutrients exhibit interactions in respect of yield and yield components (Fischer 1998). It is generally reported that application of fertilizers enhances water use efficiency by causing greater increase in yield relative to that in evapotranspiration (Viets 1962). Evapotranspirational and transpirational water use efficiency can be increased by raising soil nutrient levels. Adequately fertilized soils promote rapid leaf area expansion, thus increasing transpiration, and more rapid ground cover, thus reducing evaporation and increasing evapotranspirational water use efficiency. Raised soil nutrient levels seem to exert additive effects on water use efficiency, and increasing or optimizing yields by adequate application of fertilizers will increase transpiration efficiency of the crop plants (Schmidhalter and Studer 1998). Plants which have adequately used fertilizers may also show higher drought tolerance (Lahiri 1980; Wang et al. 2011). Phosphorus, in a balanced soil fertility program, increases water use efficiency and helps crops achieve optimal performance under limited moisture conditions (Wang et al. 2011). In sandy soils, water use efficiency for total dry matter production is increased by potassium application (Schmidhalter and Studer 1998; Prasad et al. 2000). Additions of organic materials to soil increases soil water-holding capacity, which in turn improves water availability to plants (Fan et al. 2005).

2.7 Factors Affecting on Total Water Use of Crop

2.7.1 Plant factor

Rate of transpiration, expanse of the root system and permeability characteristics of root cells are the principal plant factors that influence the water absorption. The C_3-plants such as wheat and barley, have low water use efficiency couple with low photosynthetic rates; C_4-plants such as maize and sugarcane have high water use efficiency with a higher rate of photosynthesis and CAM (Crassulacean acid metabolism plants) consume much less water and include desert plants and the pine apple (Majumdar 2002). High rates of crop growth during winter without adequate spring rainfall can induce drought stress leading up to and during anthesis and grain filling, limiting yield and lowering overall water use efficiency. The best combination of sowing rate and row spacing will be influenced by the amount of growing season rainfall, the available soil moisture and the distribution of rainfall (Sadras and Mc Donald 2012). Hooda et al. (1999) reported that maximum water use efficiency of field pea was noticed under 30 cm x 10 cm followed by 40 cm x 10 cm. This is on account higher grain yield under 30 cm x 10 cm treatment and water use is directly related to grain yield and consumptive use of water.

2.7.2 Soil factor

A soil structure is important in plant growth as it influences the amount and nature of porosity and regulates water, air and heat regimes in the soil besides affecting mechanical properties (Majumdar 2002). A recommended soil moisture tension also may depend on soil texture. If it is a recommendation to irrigate at 70 centibars; this corresponds to an approximate 30 percent depletion in soil moisture in clay loam and an approximate 60 percent depletion in sandy loam (Hason et al. 2007).

2.7.3 Management factor

Pal et al. (1991) noted that important stages for irrigation in black gram were branching, flowering and pod development stages and three irrigations at these stages gave the highest yield. There was 107.9 % more than that under rainfed condition. The consumptive use of black gram was 474.80 mm under 3 irrigations at Kalyani, West Bengal. Krishnamurti et al. (1984) and Mehta et al. (1987) notes similar effect of irrigations on yield. Tillage creates changes in the soil surface that breaks apart the surface soil layer, including soil crusts, which in turn leads to an initial increase in the rate of water infiltration into the soil and ultimately increases soil water storage. Disturbing the soil surface can also cause increased soil water evaporation compared to residue-covered surfaces or undisturbed surfaces because of the exposure of moist soil to the atmosphere. Burns et al. (1971) and Papendick et al. (1973) demonstrated that disturbing the soil surface with tillage increased soil water evaporation rates compared to untilled areas. Sauer et al. (1996) observed that surface residue decreased soil water evaporation by 34 to 50 % and creating a 15 cm bare strip with tillage increased soil water evaporation only 7 % compared to weathered residue cover. Deibert et al. (1986) stated that proper soil management could lead to both increases in precipitation storage efficiency and WUE; however, tillage effects on storage efficiency were minimal in their studies.

CHAPTER III
MATERIALS AND METHODS

The field experiments were conducted to study yield and water use efficiency of black gram under the effect of balanced fertilizers and straw residue management in Maubin Township and Daik U Township from November, 2015 to March, 2016. The experiments were carried out the different locations under same season.

3.1 Experimental Site

These study were conducted at the field of Pan-Pin-Su Village, Maubin Township, Ayeyarwaddy Division and Phaung We Village, Daik U Township, Bago Division. Maubin township is situated at 16˚ 73' N latitude and 96˚ 65' E longitude with the elevation of 13 meters above the sea level. Daik U township is situated at 17˚ 33'N latitude and 96˚ 48'E longitude with the elevation of 18 meter above the sea level.

3.2 Climate of the Study Area

Monthly rainfall and maximum and minimum mean temperature during the experimental period in Maubin Township and Daik U township are shown as in Figure 3.1 and 3.2.

3.3 Experimental Design and Treatments

The experiments were set in 2 × 5 factorial in a randomized complete block design with three replications in which one of factors was to study the effect of mulching (covering with 3 ton fresh rice straw residue per hectare) and the second one was to study the management effect by balanced fertilizers. Black gram variety (Yezin -3) was used as a tested cultivar in this study. In two experiments, the individual plot size was area of 5 m × 3 m and total experimental area was 1000 m^2 including the space. Between each plot and block, 1 m was apart. Fresh rice straw was covered the soil for mulch treatments at the rate of 3 ton biomass ha^{-1} after sowing of black gram.

Treatments were arranged as follows;

Factor A- Cover effect (Mulching)

(1) M_0=with no straw mulching

(2) M_1=with rice straw mulching

Factor B - Balanced Fertilizer application

(1) F_0= non- fertilizer application

(2) F_1= 14 - 0 - 0 NPK kg ha^{-1}

(3) F_2= 14 - 19 - 0 NPK kg ha^{-1}

(4) F_3= 14 - 19 - 32 NPK kg ha^{-1}

(5) F_4= 14 - 19 - 32 NPK kg ha^{-1} plus 0.025 $(NH_4)_6$ Mo_7 $O_{24}.4$ H_2O kg ha^{-1}

3.4 Management of Experiments

3.4.1 Planting and cultural management

The land was thoroughly prepared with the one deep strokes of ploughing, two to three strokes of harrowing and one stroke of leveling with a tractor before planting. All fertilizer treatments with urea, T. super and potash were applied as basal except ammonium molybdate fertilizer. Ammonium molybdate fertilizer at the rate of 0.025 kg ha^{-1} was applied as seed treated with the mixture of soil. Plant spacing was 0.3 m × 0.1 m, comprising 16 rows in one experimental plot and 31 plants in each row. The seed rate used was 20 - 25 kg ha^{-1} and five seeds per hole were sown on 16^{th} November, 2015 in Maubin township and 30^{th} November, 2015 in Daik U township. Replanting was done within 7 days after sowing (DAS) and thinning was done at 14 DAS, leaving two plants per hole.

Weeds were controlled two times by hand, first at 16 DAS and the later at 28 DAS. Pyrifos 40% EC was sprayed about four times for pest control especially armyworms in all plots.

3.4.2 Soil sampling and analysis

Before sowing the crop, a composite surface soil sample at the depth of 0 - 15 cm of these experimental sites was collected and analyzed to determine the soil physico-chemical properties. After harvesting, a composite soil sample from each treatment plot was collected again and analyzed to compare the changes of soil physical and chemical properties. The analyzed soil physical and chemical properties including with their determination methods are shown in Table 3.1, 3.2 and 3.3.

Table 3.1 Soil analysis methods

Parameter	Determination methods
Soil Texture	Pipette method
Soil pH	1 : 2.5 (Soil : Water) pH meter
Total N	Modified Kjeldahl Digestion method
Available P	Bray method (I)
Available K	Atomic absorption spectrophotometer
Organic Carbon	Walkley and Black method
Bulk density	Bulk density measurement of disturbed soil
Cation Exchange Capacity (CEC)	Bascomd's method
Electrical Conductivity (EC)	1 : 5 (Soil : Water)

Table 3.2 Soil physico-chemical properties of tested soil (Maubin Township)

Parameter	Analytical result	Evaluation
Soil Texture		Silty clay
Soil pH	5.84	Moderately acid
Total N (%)	0.18	Low
Available P (ppm)	6.83	Low
Available K (mg kg^{-1})	13.07	Medium
Organic Carbon (%)	0.91	Very Low
Bulk density	1.33	-
Cation Exchange Capacity cmol (+)kg^{-1}	21.33	Medium
Electrical Conductivity (dsm^{-1})	0.21	Low

Table 3.3 Soil physicochemical properties of tested soil (Daik U Township)

Parameter	**Analytical result**	**Evaluation**
Soil Texture		Silt loam
Soil pH	4.34	Extremely acid
Total N (%)	0.12	Low
Available P (ppm)	7.37	Low
Available K (mg kg^{-1})	5.44	Low
Organic Carbon (%)	0.88	Very Low
Bulk density	1.37	-
Cation Exchange Capacity cmol (+)kg^{-1}	5.05	Very Low
Electrical Conductivity (dsm^{-1})	0.13	Low

3.5 Determination of Soil Water Storage

To study the changes of soil water status and soil water storage, determinations of soil moisture at each treatment were done every 18 days after the crop sowing, before the crop sown, and at the time of the harvesting. Soil moisture was determined by using gravimetric method (Hanks and Ashcroft 1980). To measure the soil moisture, soil samples at the 15 cm depth were collected and immediately weighed by using 3 digit-electric balance (Model 20002). Then, the samples were systematically brought by containers and sent to department of Soil and Water Science, Yezin Agricultural University to determine the weight of oven dried soils at 105 °C for 48 hours and to set the complete dry soil weight.

Soil Moisture was determined by using the following equation;

$$P = \frac{W_w - W_d}{W_d} \times 100$$

(Scott 2000)

P = Moisture content percentage on dry weight basis

W_w = Wet soil weight

W_d = Dry soil weight

Soil water storage was calculated by using the following formula and amount of rainfall during the crop growing season (initial to harvest) was added in calculation of soil water storage.

$$SWS = \frac{P \times G_a \times D}{100}$$

(Kannan et al.2009)

Where,

P = Moisture content percentage on dry weight basis

G_a = Apparent specific gravity of the soil

D = Depth of the soil (cm)

SWS = Soil water storage in a given soil depth (cm) x 10= mm

3.6 Water Use Efficiency (WUE)

Water use efficiency is a measure of grain yield (kg ha^{-1}) per total water use (mm) and expressed as kg ha^{-1} mm^{-1} (Gregory 1991).

Total water use (mm) = (Water content at sowing – Water content at maturity)

+

(Rainfall or additional water between two periods of soil sampling)

(Viets 1962)

3.7 Data Collection

3.7.1 Measurement of parameters of growth, yield and yield components

3.7.1.1 Plant height (cm)

To measure the plant height, firstly five plants were randomly selected and fixed with labeled for each treatment. Then, plant heights (cm) were recorded at 10 days interval starting from 10 DAS, days after sowing. Measuring plant height was from the base of the plant to the tip of uppermost leaf. Measurement was from 10 to 80 DAS.

To determine yield and yield component characters of black gram, 5 plant samples from 2 x1 m^2 of each plot were selected and actual yields were also recorded.

3.7.1.2 Number of pods per plant

At harvesting, the number of pods per plant was counted from five selected sampled plants.

3.7.1.3 Number of seeds per pod

The number of seeds per pod was counted in 10 pods from the five sampled plants.

3.7.1.4 Hundred seed weight (g)

A random sample of hundred of well developed and dried seeds were weighed and recorded by using a 2- digit electrical balance (Model cs 200).

3.7.1.5 Seed yield

Seed yield was recorded from 2 m × 1 m area of each plot and the pods were harvested, hand threshed and sun dried. Seed yield per plot was calculated and expressed as kg ha^{-1}.

3.7.1.6 Total dry matter (TDM)

Total dry matter was measured at the time of harvesting from 5 sample plants. The whole plants were collected at sampling. Firstly, the roots of sample plants were cut and removed. All sample plants were dried at 70˚ C for 3 days in an oven.

3.7.1.7 Harvest index (HI)

Harvest index was calculated by the following equation given by (Donald and Hamblin 1976)

$$\text{Harvest Index} = \frac{\text{Economic yield(kg ha}^{-1}\text{)}}{\text{Biological yield or yield of total produce (kg ha}^{-1}\text{)}}$$

3.8 Statistical Analysis

The data were subjected to analysis of variance (ANOVA) by using Statistix (version 8.0) program. Treatment means comparison was performed by using Least Significant Differences (LSD) test at 5 % probability level.

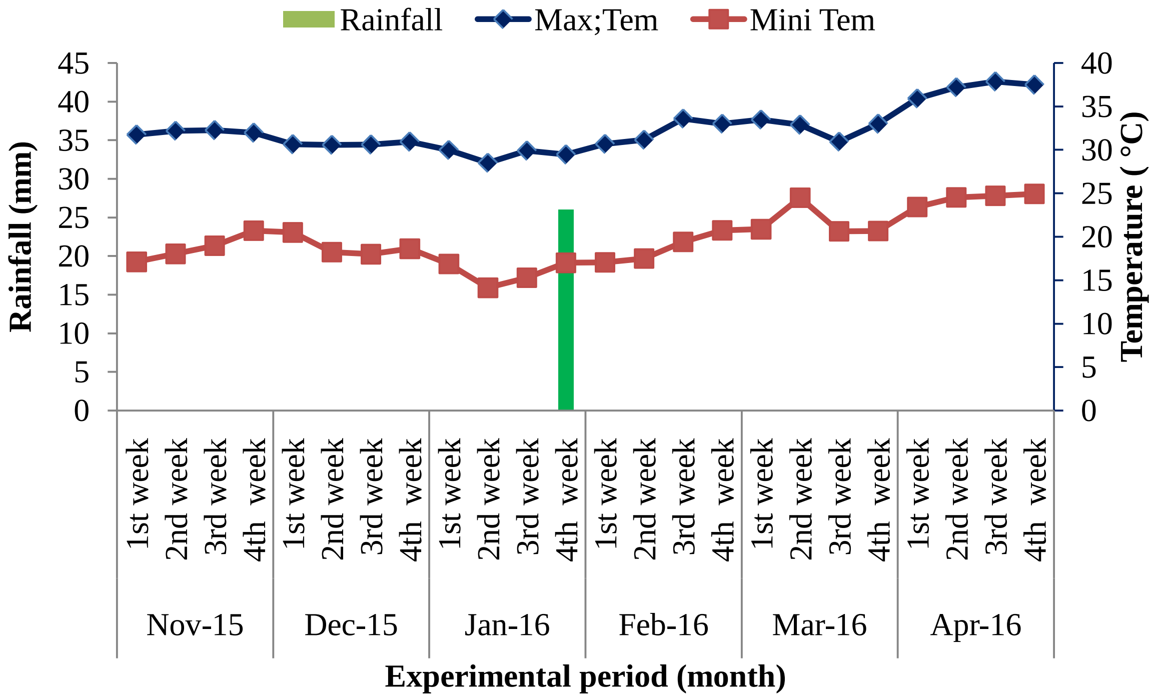


Figure 3.1 Monthly average rainfall, maximum and minimum temperature during the experimental period in Maubin Township (November, 2015 to April, 2016)

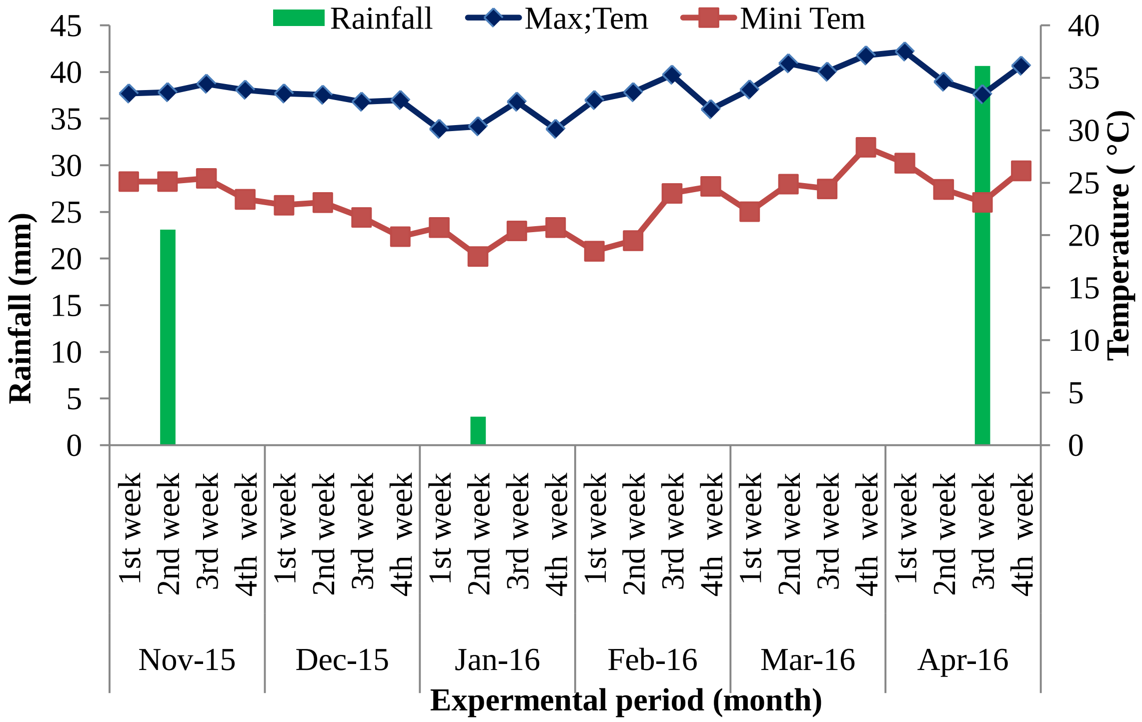


Figure 3.2 Monthly average rainfall, maximum and minimum temperature during the experimental period in Daik U Township (November, 2015 to April, 2016)

CHAPTER IV
RESULTS AND DISUSSION

4.1 Field Experiment in Maubin Township (winter season, 2015)

The experiment was conducted on the 16^{th} November, 2015 in Maubin Township, Ayeyarwaddy Division after rice harvested. In this region, the farmers used to have been traditionally practicing that the stubbles were left after rice cultivation to keep the soil moisture and then they cultivated pulses.

4.1.1 Changes of soil fertility status

4.1.1.1 Changes in soil pH

Soil pH of each treatment after conducting experiment was significantly changed compared with the experiment before conducting as in (Table 4.1). Soil pH of M_0F_1, M_0F_2 and M_1F_3 became slightly acidified while others approached to slightly neutral. Increased of soil pH by M_1F_2 was 0.6 units which was higher than that of M_0F_4 (0.49 unit). On the other hand, addition of rice straw as mulching occurred the slightly decrease of soil pH in M_1F_3 (0.28 units) which was comparatively lower than that of M_0F_1 (0.53 units). Similar results were observed by Butterly et al. (2013). In their discussion, crop residues are important for the redistribution of alkalinity within soils and effects are inconsistent in the field due to confounding soil processes and agronomic practices.

4.1.1.2 Changes in organic carbon

It was observed that soil organic carbon (SOC) accumulation in soils due to different treatments was considerably increased in after conducting experiment except in M_0F_0. Changes in soil organic carbon in M_1F_3 was 0.56 % which was the greatest amount of all increase in SOC. Changes of SOC are relatively dynamic and can be greatly influenced by many agricultural practices (Heenan et al. 2004). In addition, Liu et al. (2006) pointed out that a very efficient and environmental friendly sequestration of SOC pools could be achieved even by decreasing nitrogen fertilizer inputs, when the amount of straw returned to the field is greatly increased.

Table 4.1 Comparison of soil fertility status before and after application of balanced fertilization and straw residue management on black gram grown after rice in Maubin Township

Treatment	pH water (1:2.5)	Organic Carbon (%)	Total N(%)	Avail P (Bray) ppm	Avail K mg kg^{-1}	CEC cmol (+) kg^{-1}
Before	5.84 (0.21)	0.91 (0.02)	0.18 (0.002)	6.84 (0.03)	13.07 (0.05)	21.32 (0.03)
M_0F_0	5.91 (0.03)	0.82 (0.62)	0.17 (0.002)	8.58 (0.03)	5.96 (0.03)	21.45 (0.05)
M_0F_1	5.31 (0.02)	1.33 (0.05)	0.20 (0.01)	9.17 (0.05)	8.53 (0.06)	20.83 (0.09)
M_0F_2	5.72 (0.03)	1.14 (0.03)	0.19 (0.01)	9.81 (0.01)	7.16 (0.05)	21.31 (0.02)
M_0F_3	5.92 (0.02)	1.27 (0.02)	0.19 (0.01)	8.59 (0.05)	9.81 (0.01)	22.12 (0.01)
M_0F_4	6.33 (0.02)	1.04 (0.03)	0.19 (0.01)	7.25 (0.02)	9.79 (0.02)	21.30 (0.05)
M_1F_0	6.21 (0.02)	1.25 (0.04)	0.20 (0.01)	7.92 (0.03)	7.92 (0.04)	20.16 (0.06)
M_1F_1	6.06 (0.02)	1.15 (0.05)	0.20 (0.01)	7.21 (0.04)	8.58 (0.03)	19.93 (0.05)
M_1F_2	6.43 (0.04)	1.16 (0.05)	0.20 (0.01)	7.37 (0.04)	8.01 (0.04)	22.39 (0.03)
M_1F_3	5.56 (0.03)	1.47 (0.06)	0.20 (0.01)	8.37 (0.02)	8.66 (0.01)	20.28 (0.10)
M_1F_4	5.85 (0.02)	1.24 (0.05)	0.21 (0.01)	8.27 (0.02)	9.18 (0.03)	20.00 (0.04)

Numbers in the parentheses means standard deviation.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0- 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.1.3 Changes in total nitrogen (N)

A slight decrease in total nitrogen content was observed only in the control treatment, no mulching without fertilizer application. However, the remaining treatments showed the increment of total nitrogen content when compared with the soil condition before conducting the experiment. The greatest increment (0.21) was observed in M_1F_4 Similarly, Siczek and Lipiec (2011) found that the nitrogenase activity was higher in the mulched when compared to the un-mulched soils in every level of compacted soils. The reason why straw mulching increased soil enzyme activities is mainly by the evidence of changes in soil physical, chemical, and biological characteristics due to soil enzyme activities (Jin et al. 2009).

4.1.1.4 Changes in available phosphorus (P)

Generally, increment of available phosphorus in soil after experiment was observed in this study. This finding was supported by Sinkevičienė et al. (2009). In their observation, there was a tendency towards a higher amount of available phosphorus in the medium clay loam soil with mulched plots in 2005–2006. The reason of increased in available P in soil was assumed that like nitrogen, organic phosphorus in addition of mulch and applied fertilizers was converted to inorganic phosphate through the process of mineralization.

4.1.1.5 Changes in available potassium (K)

It was a surprise reduction of available K in soils after conducting experiment. The maximum reduction (7.11) was observed in control, the treatment without mulching and application of fertilizer. The reason was explained by Li et al. (2014). The crop residues added as mulching could absorb large amount of aqueous solution to preserve K^+ indirectly during the initial decomposition period. These crop residues could also directly adsorb K^+ via physical and chemical adsorption in the later period, allowing part of this K^+ to be absorbed by plants for the next growing season.

4.1.1.6 Changes in cation exchange capacity (CEC)

This study showed a slight decrease in CEC of most treatments excluding control, M_0F_3 and M_1F_2 when compared with before conducing experiment. In Tian and Brussaard (1997)'s report, plant residue mulch resulted in decline of SOM and ECEC during two years of cropping following six years of grass fallow. Generally recommended liming and fertilization practices will vary for soils with widely differing cation exchange capacities. Higher-CEC soils (greater than 10 meq/100g), on the other hand, experience little cation leaching, thus making fall application of N and K a realistic alternative (Mengel 2017).

4.1.2 Growth parameter

4.1.2.1 Plant height

Plant height average as affected by rice straw mulching throughout the growing season was presented in (Table 4.2). The trend of plant heights due to different treatments were gradually increased from 10 days after sowing (DAS) to 70 DAS. However, the distance between two trends was significantly far at 80 DAS. The maximum plant height (19.94 cm) with rice straw mulching and the minimum (13.77 cm) without rice straw mulching were occurred at 80 DAS. In this study, it was noted that the mean plant heights due to mulching effects were highly significantly different in all growth stages ($Pr < 0.001$) except 0.05 level at 60 DAS. The reason for higher plant growth found in mulching treatment was that increase in soil temperature and moisture content stimulated root growth which lead to greater plant growth. Similarly, Bhardwaj et al. (2011) found that mulched plants usually grew and matured more uniformally than unmulched plants.

Trends of mean plant height due to balanced fertilizer applications were shown in Table 4.2. The significant differences in plant height ($Pr < 0.05$) were occurred in 10 DAS and 80 DAS and the rest were not significant at 0.05 levels in (Table 4.2). The trends of plant height due to complete fertilization (F_3; NPK fertilizers and F_4; NPKMo fertilizers) lied at the uppermost position than the others and the trend of non fertilizer application F_0 was at the lowermost. At 80 DAS, the highest plant height (18.58 cm) was resulted in F_3; NPK fertilizers and followed by 17.33 cm in F_4; NPKMo fertilizers, 16.89 cm in F_2; NP fertilizers, 16.88 cm in F_1; N fertilizer and 14.60 cm in F_0; non-fertilizer application respectively. The lowest plant height (14.60 cm) was produced from F_0 (control). The result of present study showed the responses of plant height due to balanced fertilizer application. The results are in line with Ali et al. (1996) who observed significantly higher plant height in mungbean crop when applied NPK at the rate of 60-100-100 kg/ha. The result was agreement with Bhattacharya et al. (2004) who observed that a co-application of macronutrients and micronutrients tended to higher plant height.

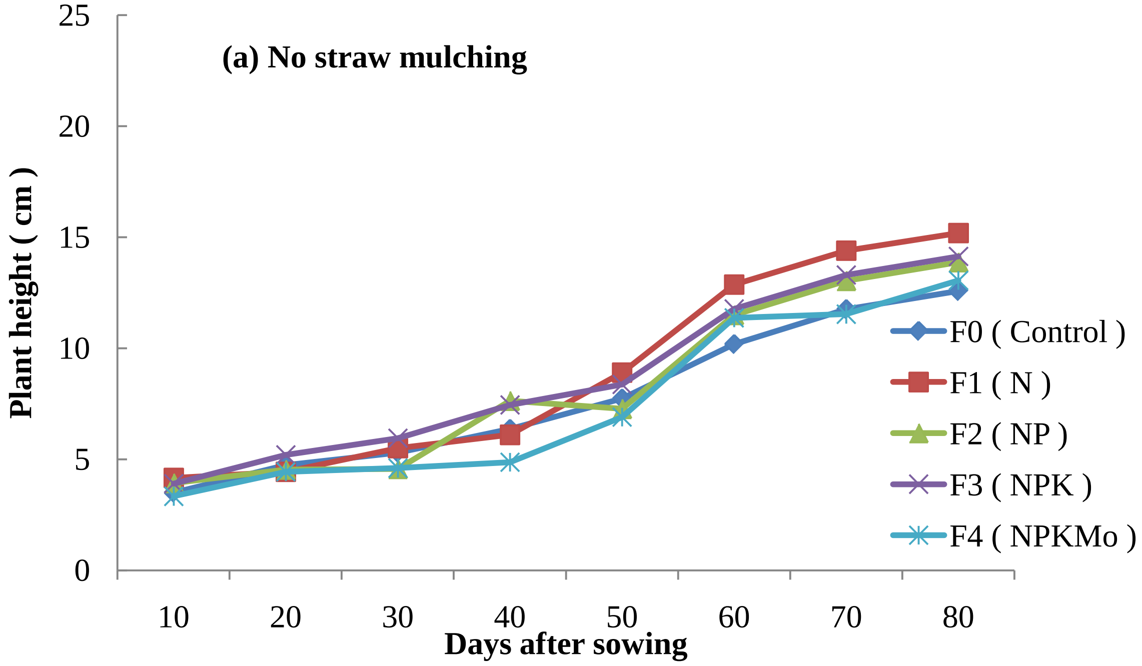
In this study, there was no interaction effect between balanced fertilizers and rice straw mulching at all growth stages except at 10 and 30 DAS at 0.05 level with significance. At 10 DAS, this result showed that the highest plant height (5.71cm) was found in M_1F_4; NPKMo with rice straw Mulching and the lowest plant height (3.33 cm) was observed from M_0F_4; NPKMo with no straw Mulching (see in Figure 4.1 a and b , Appendix 2). The difference in plant heights might be the indirect effect of moisture stress through without mulching. This result was similar with the finding of Baroowa et al. (2012) who observed that drought stress had been found to decline the linear growth of shoots in both the cultivars of black gram and green gram. At 30 DAS, the lowest plant height (4.57 cm) was unexpectedly occurred in M_0F_2; NP with no straw mulching treatment and was compared with higher plant height (7.64 cm) of M_1F_2; NP with rice straw mulching. In this situation at 30 DAS (November), the temperature (maximum: 32.24˚C and minimum 18.63˚C) and humidity (maximum 87.33 % and minimum 78.53 %) were occurred.

In this study, the plant heights produced by balance fertilization with rice straw mulching were greater than that produced by balanced fertilization without rice straw mulching (see in Figure 4.1 a and b). Especially it can be clearly seen when the effect of M_0F_1 (N fertilizers without rice straw mulching) and the effect of M_0F_0 (non-fertilizer application without rice straw mulching) on plant heights were compared. N shortage within plant tissue results in reduction of foliage and roots expansion, loss in photosynthetic efficiency and disturbance of all metabolic functions (Marschner 1995). It was observed in Maize crop by Woldesenbet et al. (2016**)** stated that the tallest plant was recorded from the application of 92 kg N ha^{-1} and the shortest from no N application.

Table 4.2 Mean effect of balanced fertilizers and straw residue management on plant height of black gram during winter season, 2015 (Maubin Township)

Treatment	Plant height (cm)							
	10DAS	**20DAS**	**30DAS**	**40DAS**	**50DAS**	**60DAS**	**70DAS**	**80DAS**
Mulching (M)								
No Straw Cover (Mo)	3.77 b	4.67 b	5.18 b	6.48 b	7.83 b	11.54 b	12.80 b	13.77 b
Rice Straw Cover (M_1)	4.82 a	5.78 a	7.20 a	8.91 a	11.55 a	13.89 a	17.14 a	19.94a
$LSD_{0.05}$	0.38	0.48	0.57	1.08	1.63	1.72	1.69	1.43
Fertilizer (F)								
F_0 (control)	3.75 b	4.97	5.45	6.77	8.22	10.89	13.75	14.60 b
F_1 (N)	4.20 ab	5.15	6.22	7.42	10.19	12.70	15.16	16.88 a
F_2 (NP)	4.30 ab	5.13	6.10	8.19	9.97	12.48	14.94	16.89 a
F_3 (NPK)	4.70 a	5.43	6.64	8.68	10.47	13.87	16.27	18.58 a
F_4 (NPKMo)	4.52 a	5.44	6.55	7.45	9.62	13.63	14.73	17.33 a
$LSD_{0.05}$	0.60	0.75	0.90	1.70	2.58	2.73	2.68	2.27
Pr >F								
Mulching (M)	<0.0001	0.0001	<0.0001	0.0002	0.0001	0.0103	<0.0001	<0.0001
Fertilizer (F)	0.0392	0.6302	0.0864	0.2018	0.4194	0.2065	0.4288	0.0267
M× F	0.0058	0.1953	0.0039	0.1041	0.3326	0.3385	0.3598	0.0631
CV (%)	11.58	11.90	11.99	18.30	21.97	17.70	14.73	11.09

Means followed by the same letter within the column are not significantly different at LSD test 5% level.
M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1}) F_0 = non fertilizer application,
F_1= 14- 0-0 NPK kg ha^{-1}, F_2= 14-19-0 NPK kg ha^{-1} F_3 = 14-19-32 NPK kg ha^{-1}, F_4 =14-19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}



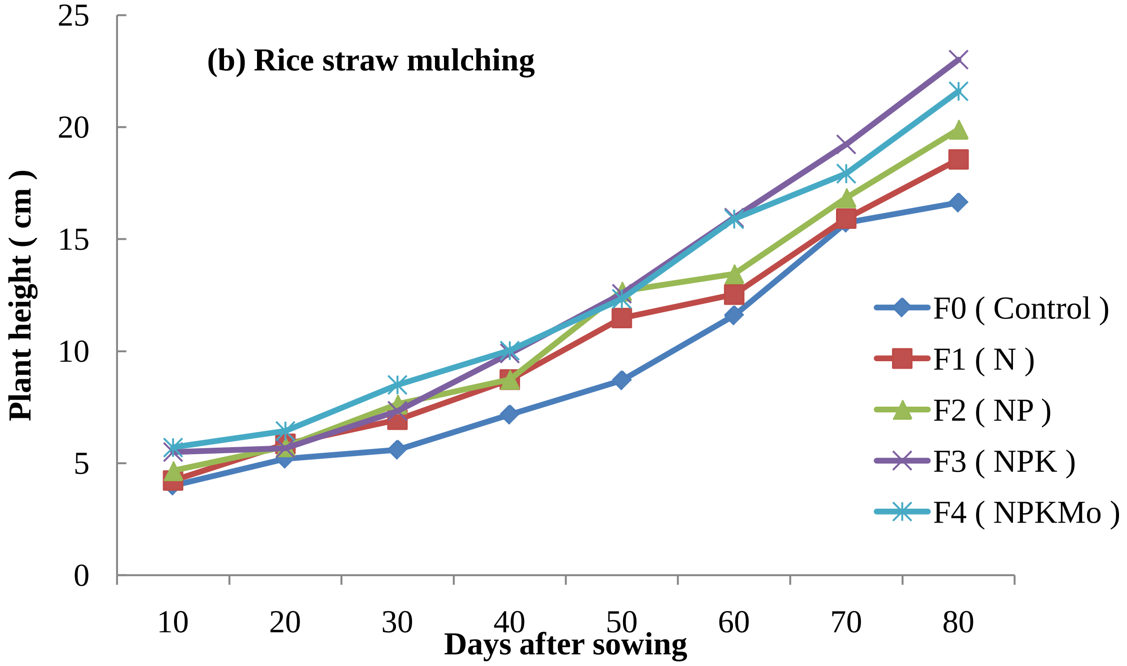


Figure 4.1 **Mean comparison of plant height (a) no straw mulching (b) rice straw mulching as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.3 Yield and yield components parameters

4.1.3.1 Seed yield

Response of mean seed yields due to rice straw mulching was shown as in (Table 4.3). It was observed that the effect of rice straw mulching on seed yield was highly significantly different ($Pr < 0.001$). The seed yield (680.53 kg ha^{-1}) of rice straw mulching (M_1) was significantly higher than that (516.24 kg ha^{-1}) of no rice straw mulching (M_0). The results of present study were agreed with Van Den Bergh and Lestari (2001)'s studying on the improvement of local cultivation of soybean with 86 farmers in Indonesia. They found that the use of rice straw spreading over plots to a depth of 4 - 10 cm could increase soybean yield across sites by 41 %. Furthermore, Verma and Kohnke (1951) had proved that there were potentially beneficial effects of rice straw mulch to reduce soil temperature, soil surface crusting and evaporation of moisture.

There was a significant difference on seed yield as affected by balanced fertilizers at 1 % level (Table 4.3). It was observed that effect of balanced fertilizer application increased seed yield. The maximum seed yield (677.86 kg ha^{-1}) was obtained in F_4; NPKMo fertilizers and the minimum (528.55 kg ha^{-1}) was in F_0; non-fertilizer application. The response of F_1; N fertilizer increased (6.33 %) seed yield over F_0; non-fertilizer application, the response of F_2; NP fertilizers increased (4.86 %) seed yield over F_1; N fertilizer, the response of F_3; NPK fertilizers increased (7.62 %) seed yield over F_2; NP fertilizers and the response of F_4; NPKMo fertilizers increased (6.88%) seed yield over F_3; NPK fertilizer and (28.25 %) seed yield over F_0; non-fertilizer application. It was agreement with the findings of Bhattacharya et al. (2004). They reported that application of 20 kg N ,40 kg P_2O_5, 40 kg K_2O and 1 kg ammonium molybdate per hectare resulted the high grain yield of black gram and green gram. The relationship between P and Mo in tobacco plants is also influenced by N, for application of NH_4-N can enhance the concentrations of both native and applied P, and the P can enhance Mo concentrations when Mo is applied, but not influence Mo nutrition in the absence of added Mo (Schwamberger and Sims 1991). Brkic et al. (2004) also discussed that the application of molybdenum stimulated nodulation and biological nitrogen fixation, thus increasing the legume yield. The effect of P to increase the Mo concentrations in plants has been reported to be associated with the stimulating effect of the PO_4^{-3} ion on the uptake of Mo because of formation of a complex phosphomolybdate anion that is absorbed more readily by the plants (Barshad 1951).

In this study, there was no interaction effect between balanced fertilizers application and rice straw mulching. This indicated that the response of seed yield due to rice straw mulching was not affected by balanced fertilizers application.

From the combined effect of balanced fertilizers and straw mulching (Figure 4.2), the maximum seed yield (758.48 kg ha^{-1}) was obtained from M_1F_4; NPKMo with rice straw mulching and the minimum (444.78 kg ha^{-1}) was obtained from M_0F_0; non-fertilizer application with no straw mulching. The yield obtained from M_1F_4; NPKMo with rice straw mulching increased (27 %) seed yield over M_0F_4; NPKMo fertilizers without rice straw mulching and (23.87 %) over M_1F_0; non-fertilizer application with rice straw mulching. The results indicated that black gram production using rice straw as mulching and applying with balanced fertilizers would increase its seed yield.

Table 4.3 Mean effect of balanced fertilizers and straw residue management on yield and yield components of black gram during winter season, 2015 (Maubin Township)

Treatment	Seed yield ($kg\ ha^{-1}$)	pods $plant^{-1}$ no.	Seeds pod^{-1} no.	100 seed weight (g)
Mulching (M)				
No straw mulching(M_0)	516.24 b	7.39 b	6.23	5.42 b
Rice straw mulching (M_1)	680.53 a	10.45 a	6.39	5.67 a
LSD0.05	12.35	1.07	0.19	0.16
Fertilizer (F)				
F_0 (control)	528.55 e	6.51 b	5.97 b	5.30 c
F_1 (N)	562.00 d	7.95 b	6.22 ab	5.48 bc
F_2 (NP)	589.31 c	9.67 a	6.40 a	5.54 abc
F_3 (NPK)	634.23 b	9.97 a	6.45 a	5.61 ab
F_4 (NPKMo)	677.86 a	10.50 a	6.52 a	5.78 a
LSD0.05	19.53	1.70	0.31	0.26
Pr> F				
Mulching (M)	<0.0001	<0.0001	0.0935	0.0058
Fertilizer (F)	<0.0001	<0.0001	0.0112	0.0165
Mulching× Fertilizer	0.9138	0.6291	0.9543	0.1955
CV (%)	13.14	15.66	4.08	3.87

Means followed by the same letter within the column are not significantly different at LSD test 5% level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.3.2 Number of pods per plant

The number of pods per plant as affected by rice straw mulching are presented in (Table 4.3). There was the highly significant difference among different rice straw mulching methods ($Pr < 0.001$). The maximum number of pod per plant (10.45) was resulted in rice straw mulching (M_1) method and the minimum number of pods per plant (7.39) in non-rice straw mulching (M_0) method. The result was similar to the finding of Su et al. (2014) who observed that the application of rice straw mulch increased higher number of pod of oilseed rape over non mulching in rice-oilseed rape system. This might be due to straw mulching is retaining greater availability of soil water by controlling evaporation loss from the soil surface, and improving water infiltration (Sharma et al. 2011).

Effect of balanced fertilizers management on number of pods per plant was significantly difference at 0.01 levels as in (Table 4.3). The effect of $F_{1;}$ N fertilizer on pod number (7.95) was slightly higher than that (6.51) by F_0; non-fertilizer application but the values were statistically similar. The highest number of pods per plant (10.50) was resulted in F_4; NPKMo fertilizers that was statistically similar F_3; NPK fertilizers, (9.97) and F_2; NP fertilizers (9.67). The result of present study indicated the response of fertilizers nitrogen, phosphorus, potassium and ammonium molybdate increased the number of pod per plant. The results were comparable to the findings of Bhattacharya et al. (2004). In their results, the higher number of pods per plant in green gram and black gram production was observed by the application of 20 kg N, 40 kg P_2O_5, 40 kg K_2O and 1 kg ammonium molybdate ha^{-1}. According to Valenciano et al. (2011), foliar application of Mo to chickpea resulted in a higher number of pods per plant and a higher yield (increased from 1.87 to 2.45 g/plant). The reason of such an increase in pod number was that phosphorus played as an essential ingredient for rhizobium bacteria to convert atmospheric N_2 into an ammonium (NH_4) form which was useable by plants (Dakora and Keya 1997). Moreover, Meagher et al. (1991) explained that the role of molybdenum in normal assimilation of nitrogen by plants was well known, because molybdenum was an essential component of nitrate reductase and nitrogenase, which control the reduction of inorganic nitrate and helps in fixing N_2 to NH_3.

In this study, there was no interaction effect between balanced fertilizers application and rice straw mulching on number of pods per plant. This result indicated that the response of the number of pods per plant in rice straw mulching was not affected by balanced fertilizers application.

Among the combined effects due to balanced fertilizers and straw residue management as in (Figure 4.3), the highest number of pods per plant (12.12) was obtained from M_1F_4; NPKMo with rice straw mulching and the lowest number of pods per plant (5.68) was occurred from M_0F_0; non-fertilizer application with no straw mulching. The reason of higher pod numbers produced by complete fertilization with rice straw mulching was that molybdenum fertilization increases the drought resistance of plants by maintaining a higher degree of hydration of cell colloids (Vasil' eva and Startseva 1959).

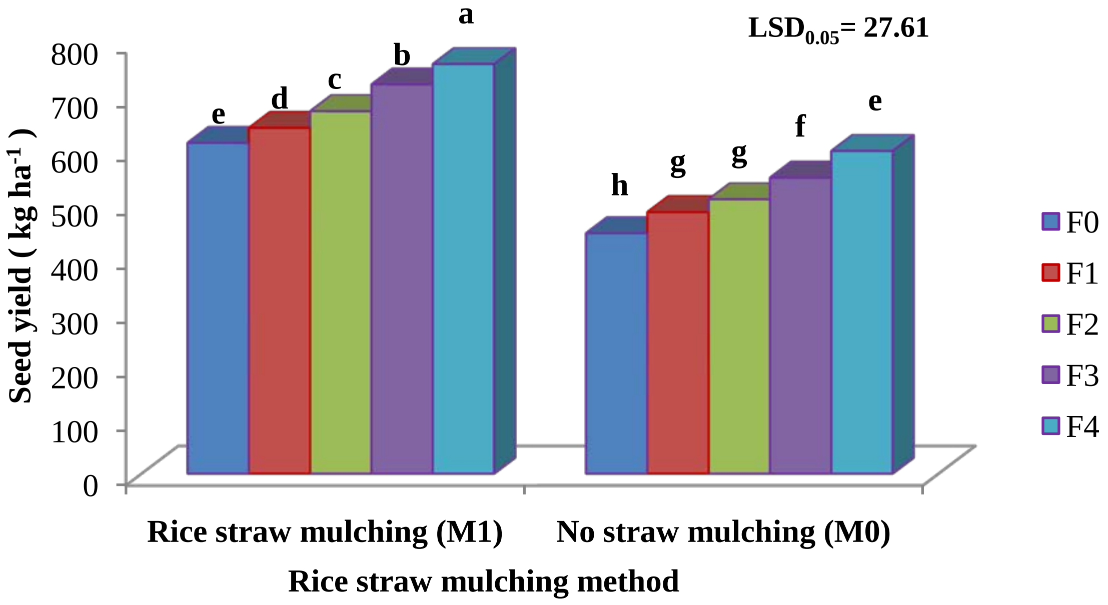


Figure 4.2 **Mean comparison of seed yield as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

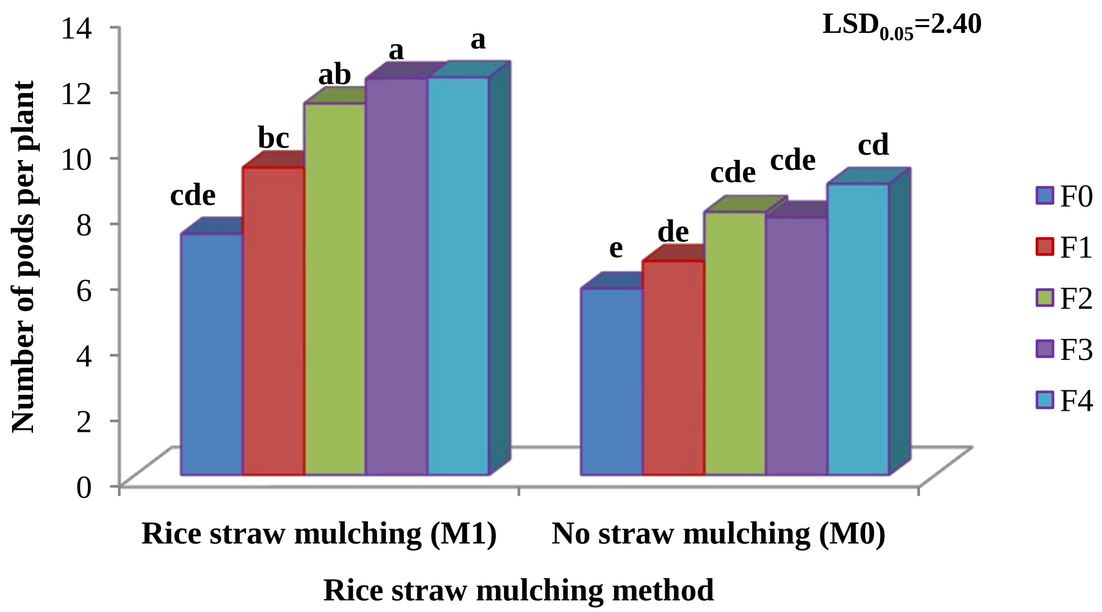


Figure 4.3 **Mean comparison of number of pods per plant as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.3.3 Number of seeds per pod

The effect of rice straw mulching on number of seeds per pod was presented in (Table 4.3). There was no significantly difference in number of seeds per pod due to rice straw mulching or not.

It was observed that effect of balanced fertilizers management on number of seeds per pod was significantly different at 0.05 levels (Table 4.3). The maximum number of seeds per pod (6.52) was resulted in F_4; NPKMo fertilizers. But it was statistically similar to F_3; NPK fertilizers (6.45) and F_2; NP fertilizers (6.40). Among the treatments, the minimum number of seeds per pod (5.97) was observed in F_0; non-fertilizers application. The reason for such an increase in seeds per pod was due to complete fertilization. Enhanced Mo concentrations due to P application might also be dependent on the presence of adequate N or addition of N (Gupta 1997).

There was no interaction effect on number of seeds per pod between balanced fertilizers and straw residue management in (Table 4.3). This result indicated that response of number of seeds per pod due to rice straw mulching method was not affected by balanced fertilizers application.

In combined effect of balanced fertilizers and rice straw mulching as in (Figure 4.4), the higher number of seeds per pod (6.60 and 6.57) was collected from the M_1F_4; NPKMo with rice straw mulching and M_1F_3; NPK fertilizers with rice straw mulching treatments than other treatments. Among the treatments, the lowest number of seeds per pod (5.83) was collected from M_0F_0; non-fertilizer application with no straw mulching. This study also viewed out that produced number of seeds per pod under rice straw mulching with complete fertilization showed the better performance than that under no mulching with complete fertilization. The most significance one was observed in mulching with incomplete fertilization.

4.1.3.4 Hundred seed weight

Influence of mulching with rice straw on 100 seed weight is presented in (Table 4.3). There was a significant difference ($Pr < 0.05$) in 100 seed weight by rice straw mulching. The 100 seed weight was resulted by mulching with rice straw was greater than that without mulching. The reason of such a greater value in 100 seed weight was that soils under rice straw mulching gave adequate moisture during the pod filling stage. The results was in line with the finding of Salisbury and Ross (1992) who reported that low water availability adversely affects plant development and assimilated translocation.

The effect of balanced fertilizers management on 100 seed weights are recorded in (Table 4.3). The effect of balanced fertilizer on 100 seed weight was significantly different at 0.05 levels. The maximum 100 seed weight (5.78 g) was obtained in F_4; NPKMo fertilizers. And then F_3; NPK fertilizers (5.61 g) and F_2; NP fertilizer (5.54 g) was followed respectively. The minimum 100 seed weight (5.30 g) was produced by F_0; non-fertilizer application. The results showed that there was a significant effect of ammonium molybdate as seed treatment and it produced better performance of 100 seed weight of black gram. Therefore, Domska et al. (1989) have been proved that Mo promotes the utilization of absorbed nitrates in plants and promotes N fixation in leguminous plants.

In this study, there was no interaction effect on 100 seed weight between balanced fertilizers and rice straw mulching. From the combined effects of balanced fertilizers and straw residue methods as in (Figure 4.5), the maximum 100 seed weight (5.88 g) was resulted in M_1F_4; NPKMo with rice straw mulching and the minimum 100 seed weight (5.02 g) was obtained from M_0F_0; non-fertilizer application with no straw mulching. In this case, the effect of rice straw mulching increased 100 seed weight and the effect of balanced fertilizer influenced 100 seed weight as well.

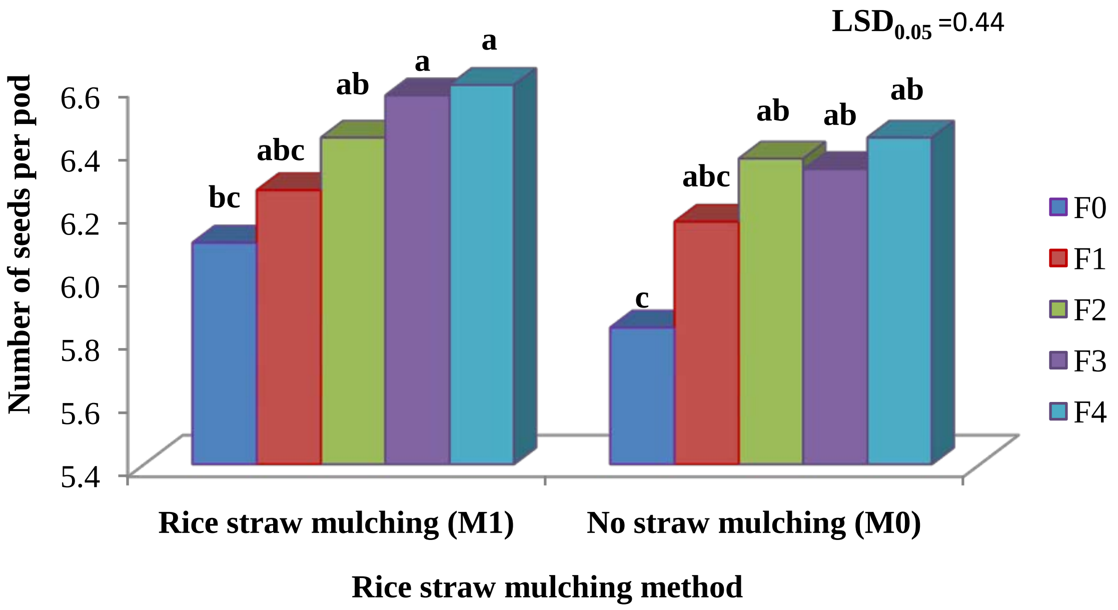


Figure 4.4 **Mean comparison of number of seeds per pod as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

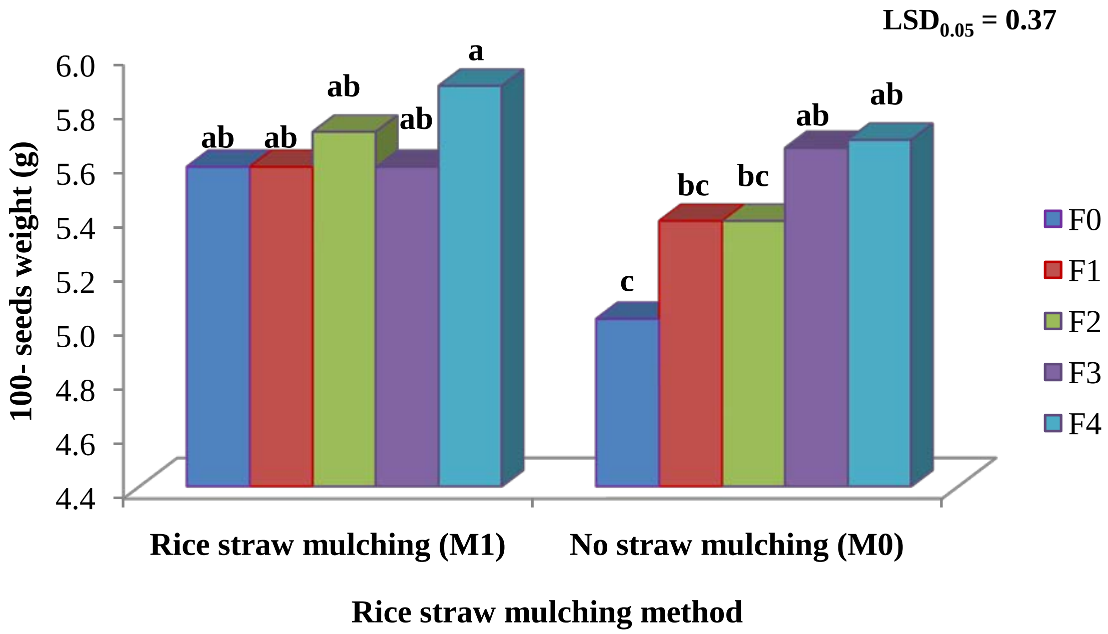


Figure. 4.5 **Mean comparison of 100 seed weight as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.3.5 Total dry matter content (TDM)

The significant difference in total dry matter (TDM) was observed at rice straw mulching at 0.01 levels at harvest (Table 4.4). The maximum total dry matter (2276.90 kg ha^{-1}) was produced by rice straw mulching and minimum total dry matter (2172.70 kg ha^{-1}) by without mulching. The result of present study was agreement with Amini et al. (2013) who observed that the biological and grain yield of lentil (mulching with 2 ton biomass ha^{-1}) was greater than that of control treatment. Furthermore, Raeini-Sarjaz and Barthakur (1997) added that using plastic or straw mulch was an efficient practice, which could alter water distribution between soil evaporation and plant transpiration. Direct evaporation from soil was often a major loss of available water because it was not contributing to biomass production. Thus, mulching materials have a positive effect on growth of black gram plant and contribute to increasing vegetative growth and yield.

There was a significant difference in total dry matter as affected by balanced fertilizers at 0.01 levels (Table 4.4). The maximum total dry matter (2426.50 kg ha^{-1}) was observed in F_4; NPKMo fertilizers and the minimum of that (2052.10 kg ha^{-1}) was resulted in F_0; non- fertilizer application. Other treatments such as F_3; NPK fertilizers, F_2 ; NP fertilizers and F_1; N fertilizer produced the dry matter yield as 2323.00 kg ha^{-1}, 2183.10 kg ha^{-1}, and 2139.40 kg ha^{-1} respectively. The result of present study also showed that there was an effect of ammonium molybdate on total dry matter production and it resulted in (18.25 %) increment over control. The findings was agreed with Gupta et al. (1976). In their study on rice crop production, Mo application enhanced CO_2 assimilation by the crop, especially at a high N dosage, by increasing both the efficiency and size of the assimilatory surface. In addition, Skarpal et al. (2013) observed that there were the positive effects of molybdenum fertilization in stages V-4 and R-1 on dry matter production of sunflower with the rates of 125 g ha^{-1} and 62 g ha^{-1}. The obvious results of the average dry matter weights of leaves and stems were increased by 26.5 % and 21.7 %, respectively.

There was no interaction effect on total dry matter between balanced fertilizers application and rice straw mulching. This indicated that the response of mulching with rice straw was not influenced by balanced fertilizers. In the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.6), it was found that the maximum total dry matter (2454.70 kg ha^{-1}) was recorded from M_1F_4; NPKMo fertilizers with rice straw mulching and the minimum (1939.10 kg ha^{-1}) was obtained by M_0F_0; non-fertilizers application with no straw mulching. This result indicated that application of ammonium molybdate with NPK fertilizers increased biological yield of black gram. Thus, black gram production with rice straw mulching produced higher total dry matter content than that without mulching and then, balanced fertilization could increase the total dry matter content as well.

Table 4.4 Mean effect of balanced fertilizers and straw residue management on total dry matter production and harvest index of black gram during winter season, 2015 (Maubin Township)

Treatment	Total dry matter ($kg\ ha^{-1}$)	Harvest Index (HI)
Mulching (M)		
No straw mulching(M_0)	2172.70 b	0.24 b
Rice straw mulching (M_1)	2276.90 a	0.30 a
LSD0.05	51.52	0.04
Fertilizer (N)		
F_o (control)	2052.10 d	0.26 c
F_1 (N)	2139.40 c	0.26 bc
F_2 (NP)	2183.10 c	0.27 ab
F_3 (NPK)	2323.00 b	0.28 a
F_4 (NPKMo)	2426.50 a	0.28 a
LSD0.05	81.45	0.02
Pr> F		
Mulching (M)	0.0005	<0.0001
Fertilizer (F)	<0.0001	0.0155
Mulching× Fertilizer	0.1393	0.7039
CV (%)	12.14	11.95

Means followed by the same letter within the column are not significantly different at LSD test 5% level.

M_0 = no mulching, M_1 = rice straw mulching (3 $ton\ ha^{-1}$)

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK $kg\ ha^{-1}$, F_2= 14 - 19 - 0 NPK $kg\ ha^{-1}$

F_3= 14 - 19 - 32 NPK $kg\ ha^{-1}$, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ $kg\ ha^{-1}$

4.1.3.6 Harvest index (HI)

Harvest index (HI) is the ratio of economic yield to biological yield and productive efficiency of a crop measured.

Mean values of HI as affected by rice straw mulching methods are presented in (Table 4.4). There was a significant difference in HI due to rice straw mulching at 0.01 levels. The treatments with rice straw mulching (3 ton ha^{-1}) produced higher value of HI (0.30) than that without mulching (0.24). Thus, under favorable soil moisture with rice straw mulching during flowering and pod filling stage was the reason for higher seed yield and harvest index.

Influence of balanced fertilization on HI in black gram production was observed in (Table 4.4) at 0.05 levels. The maximum harvest index (0.28) was produced by F_4; NPKMo fertilizer and F_3; NPK fertilizers. The minimum HI (0.26) was resulted in F_0; non-fertilizer application. Thus, application of nitrogen, phosphorus, potassium and ammonium molybdate fertilizers increased harvest index of black gram with respect to increased seed yield and biological yield.

No interaction was observed between balanced fertilizer application and rice straw mulching in (Table 4.4). This indicated that the change of HI due to rice straw mulching was not influenced by balanced fertilizer application. In the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.7), the maximum harvest index (0.31) was obtained in M_1F_4; NPKMo with rice straw mulching and M_1F_3; NPK with rice straw mulching. Then M_1F_2; NP fertilizers with rice straw mulching produced the HI (0.30) and the HI produced by M_1F_1; N fertilizers with rice straw mulching (0.29) was followed. The minimum value of HI (0.23) was resulted M_0F_1; N fertilizer without rice straw mulching and M_0F_0; non-fertilizer application without rice straw mulching. This result indicated that black gram production under rice straw mulching increased HI with increased seeds yield and biological yield and application of balanced fertilizers increased HI with promoted seeds yield and biological yield as well.

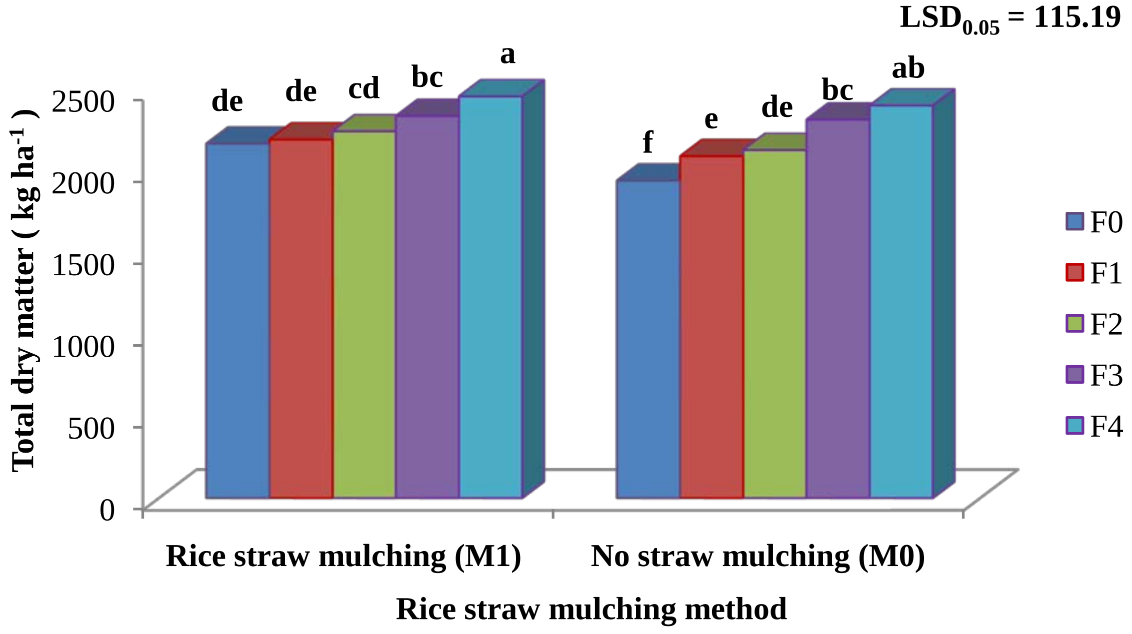


Figure 4.6 **Mean comparison of total dry matter as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

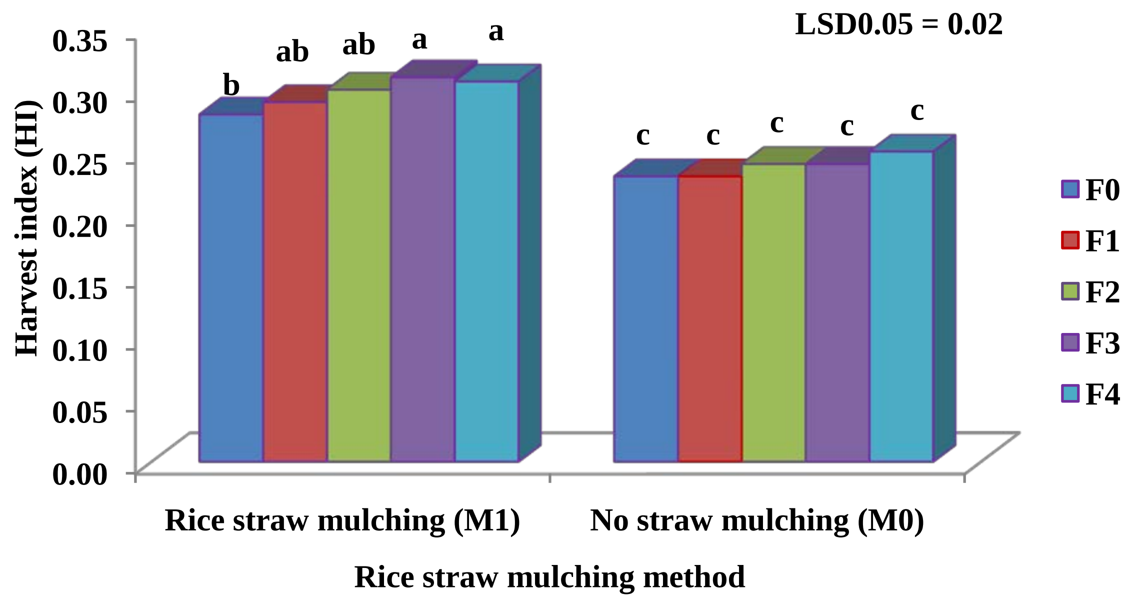


Figure 4.7 **Mean comparison of harvest index (HI) as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Maubin Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.4 Changes soil water status

Figure 4.8 shows changes of soil water status from the beginning to the end of crop grown. Initial soil water status of each plots were the same but soil water status at the end of crop grown from each plots were different. Especially soil water status under mulching restored more water than those without mulching. At the end of crop growth, the maximum amount of water (28.72 mm) was stored in M_1F_2 and the lowest amount of water was stored in M_0F_1 (21.63 mm). During the crop growth stages, it was clearly seen that much water could be comparatively stored under the plots with mulching. In the similar study of Chakraborty et al. (2008) on wheat, they discussed that the higher soil moisture status indicated the role of mulch in conserving the moisture in soil and the rate of drying of soil was slow, resulting in water availability for relatively longer period during crop growth and development. Moreover, Barbosa et al. (2016) reported that the use of mulch on the soil favored the greatest absorption of nutrients and increased the productivity of okra plant.

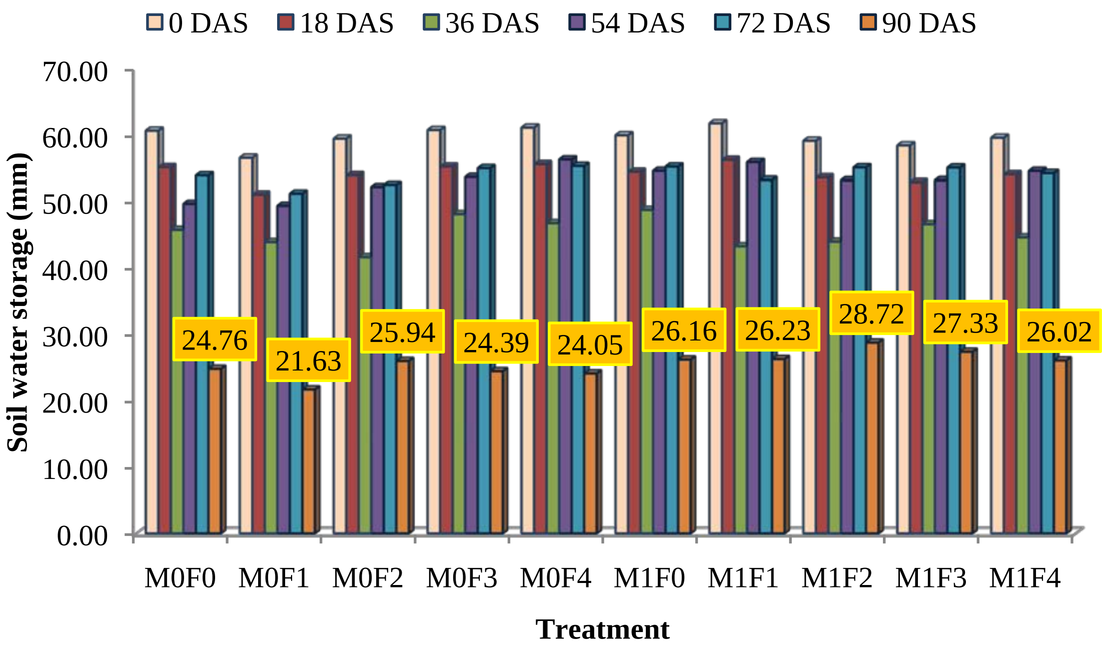


Figure 4.8 Changes of soil water status on black gram grown after rice as affected by balanced fertilization and straw residue management in Maubin Township

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.5 Total water use

The mean values of total soil water use as affected by rice straw mulching methods are presented in (Table 4.5). The effect of rice straw mulching on total water use was statistically different at 0.05 significant levels. The maximum total water use (153.01 mm) was resulted in the treatment without mulching and the minimum total water use (150.33 mm) was obtained from the treatment with rice straw mulching. The results of present study were in line with the findings of Bhattacharya et al. (1998) who observed that the mean water use was found to be highest (137 mm) in the 0 - 45 cm soil profile in no-mulch (control) conditions compared to under acacia leaf mulch (128 mm) and under glyricidia leaf (119 mm). The reason of higher water use in the treatment without mulching was that it might be attributed to higher evaporation from the soil surface in no-mulch treatment compared to very little evaporation under mulches (Singh and Bhan 1993).

The mean values of total soil water use as affected by balanced fertilizer were not statistically different as in (Table 4.5). Numerically, the highest soil water use (152.77 mm) was observed in F_4; NPKMo fertilizer, and the lowest soil water use (149.41 mm) was resulted in F_2; NP fertilizer. It was generally reported that application of fertilizers enhanced water use efficiency by causing greater increase in yield relative to that in evapotranspiration (Viets 1962). In terms of phosphorus in a balanced soil fertility program, it increases water use efficiency and helps crops achieve optimal performance under limited moisture conditions (Wang et al. 2011).

There was no interaction effect on total soil water use between balanced fertilizer application and rice straw mulching methods. This result indicated that changes of total water use due to rice straw mulching was not influenced by balanced fertilizer application. From the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.9), the maximum total soil water use (154.52 mm) was recorded in M_0F_4; NPKMo fertilizer without rice straw mulching. The minimum total soil water use (147.86 mm) was observed in M_1F_2; NP fertilizers with rice straw mulching. This results indicated that black gram crop should produce under rice straw mulching and without mulching had a significant effect on total soil water use high.

Table 4.5 Mean effect of balanced fertilizers and straw residue management on total water use and water use efficiency of black gram during winter season, 2015 (Maubin Township)

Treatment	Total Water use (mm)	Water Use Efficiency ($kg\ ha^{-1}\ mm^{-1}$)
Mulching (M)		
No straw mulching(M_0)	153.01 a	3.37 b
Rice straw mulching (M_1)	150.33 b	4.53 a
$LSD_{0.05}$	1.65	0.08
Fertilizer (N)		
F_o (control)	152.30	3.47 e
F_1 (N)	152.69	3.68 d
F_2 (NP)	149.41	3.95 c
F_3 (NPK)	151.18	4.21 b
F_4 (NPKMo)	152.77	4.45 a
$LSD_{0.05}$	2.60	0.12
Pr> F		
Mulching (M)	0.0031	<0.0001
Fertilizer (F)	0.0707	<0.0001
Mulching× Fertilizer	0.2398	0.2349
CV (%)	1.42	10.53

Means followed by the same letter within the column are not significantly different at LSD test 5% Level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.1.6 Water use efficiency

The mean values of water use efficiency of black gram as influenced by rice straw mulching are presented in (Table 4.5). There was a highly significantly difference due to rice straw mulching at 0.01 levels. The maximum value of water use efficiency (4.53 kg ha^{-1} mm^{-1}) was observed in the treatment with rice straw mulching and the minimum value (3.37 kg ha^{-1} mm^{-1}) was obtained from that without mulching. The results of present study was agreed with the findings of Bhattacharya et al. (1998) who observed that the mean water use efficiency was found to be higher under leaf mulches (0.37- 0.55 kg $ha^{-1}mm^{-1}$) compared to no mulch conditions (0.27 kg $ha^{-1}mm^{-1}$). This might be due to surface mulching which reduces evaporation by protecting the moist layer of air close to the surface from wind and moderates soil temperature. When evapotranspiration was relatively low, an increase in crop water use could result in large increases in both grain yield and WUE (Jalota and Prihar 1998).

The effect of balanced fertilizers on water use efficiency was highly significantly different at 0.01 levels as in (Table 4.5). The maximum water use efficiency (4.45 kg $ha^{-1}mm^{-1}$) was recorded in F_4; NPKMo fertilizers and the minimum water use efficiency (3.47 kg ha^{-1} mm^{-1}) was resulted in F_0; non-fertilizer application. Water use efficiency of black gram that applied by F_3; NPK fertilizers showed the result of 4.21 kg $ha^{-1}mm^{-1}$ which was the second most and that of F_2; NP fertilizers and F_1; N fertilizer gave the values of 3.95 kg ha^{-1} mm^{-1} and 3.68 kg ha^{-1} mm^{-1}respectively. This study indicated that application of balanced fertilizers increased water use efficiency (28 %) over control. The reason of increase in WUE in the treatments applied with balanced fertilizer was that raised soil nutrient levels seem to exert additive effects on water use efficiency, and increasing or optimizing yields by adequate application of fertilizers will increase transpiration efficiency of the crop plants (Schmidhalter and Studer 1998).

There was no interaction effect on water use efficiency between balanced fertilizer application and rice straw mulching. This indicated the response of water use efficiency due to rice straw mulching was not influenced by balanced fertilizer application. In the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.10), the maximum water use efficiency (5.02 kg ha^{-1} mm^{-1}) was resulted in M_1F_4; NPKMo fertilizers with rice straw mulching and the minimum (2.90 kg $ha^{-1}mm^{-1}$) was observed in M_0F_0; non-fertilizer application without rice straw mulching. Noticeably, water use efficiency of M_0F_4; NPKMo fertilizers without rice straw mulching treatment was recorded as 3.86 kg ha^{-1} mm^{-1}. In this case, it was seen that the effect of rice straw mulching increased water use efficiency of black gram and the effect of balanced fertilizers produced higher water use efficiency.

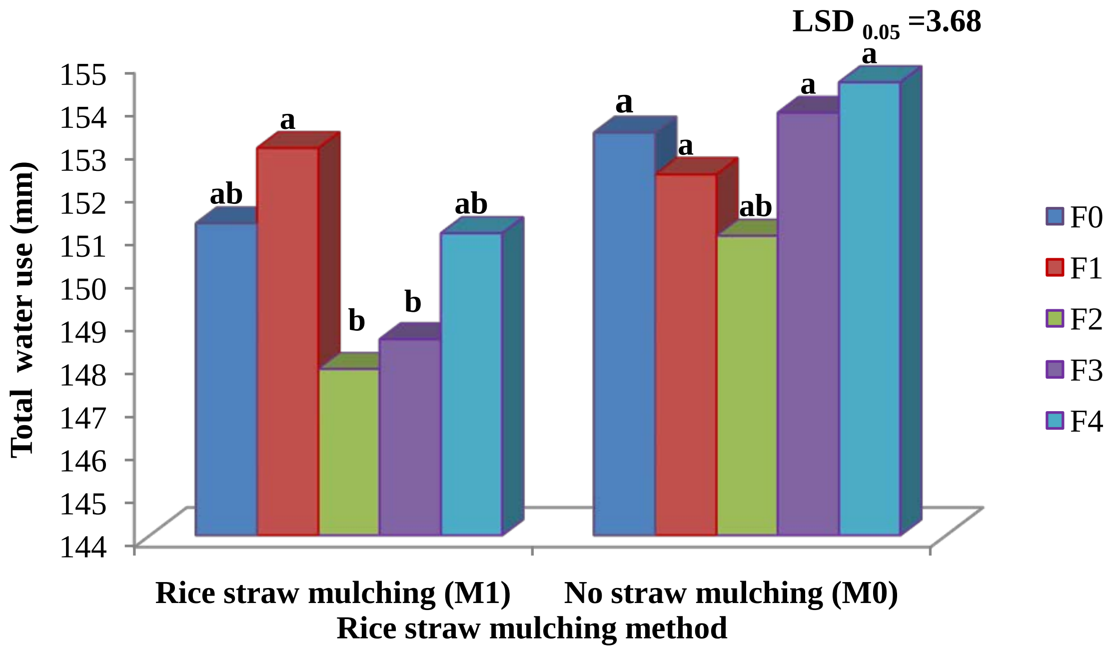


Figure 4.9 Mean comparison of total water use of black gram as affected by balanced fertilizers and straw residue management during winter season, 2015 (Maubin Township)

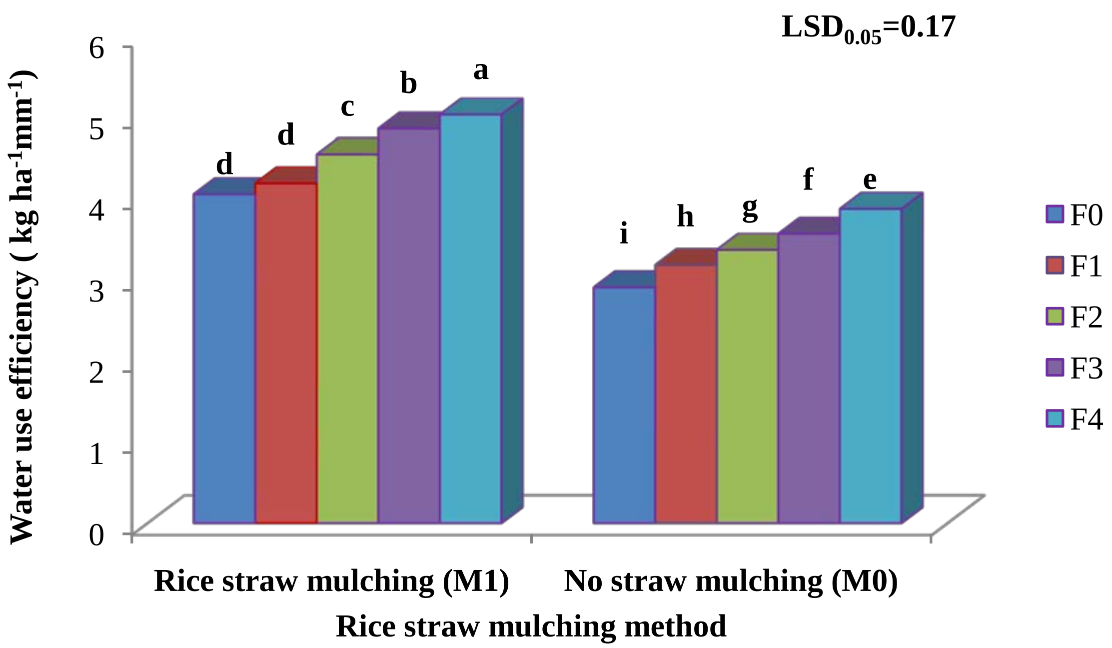


Figure 4.10 Mean comparison of water use efficiency of black gram as affected by balanced fertilizers and straw residue management during winter season, 2015 (Maubin Township)

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2 Field Experiment in Daik U Township (winter season, 2015)

The experiment was conducted on 30^{th} November, 2015 in Daik U Township, Bago Division after rice harvested. The tested soil was silt loam, pH (4.34). In this region, the farmers have been practicing in burning of rice stubble before black gram cultivation.

4.2.1 Changes of soil fertility status

4.2.1.1 Changes of soil pH

In this study, changes of soil pH under field condition due to balanced fertilization and mulching with rice straw were significantly alkalinized in all treatments after conducting experiment compared with before. The highest increased in soil pH was occurred in M_0F_1 (1.58 units) and then followed by M_1F_0 (1.21 units), M_0F_3 (1.02 units), M_0F_2 (0.93 units), M_0F_4 (0.97 units), M_0F_0 (0.89 units), M_1F_2 (0.77 units), M_1F_3 (0.70 units), M_1F_1 (0.47 units), and M_1F_4 (0.28 units) respectively. These results might be coincided with the increase in soil water used (see in Figure 4.19). Valdez et al. (2006) reported that as moisture increased with increased in soil pH together with decrease in Eh under short term effects of moisture content on soil solution pH and soil Eh. However, they concluded that the effects are especially pronounced in weakly buffered coarse textured soils.

4.2.1.2 Changes in organic carbon

This study showed that soil organic carbon content in all treatments conducted by non-mulching with balanced fertilization were reduced to a significant amount and those in treatments conducted by mulching with balanced fertilization increased slightly in after experiment. The maximum incensement of SOC (0.13%) was obtained in M_1F_4. The greatest benefit was related to the microbial promotion of rapid decomposition in organic matter due to surface mulching with complete fertilization Ros et al. (2003). Similar result was found in the study of Manns et al. (2007). They suggested that surface management with dried ground cover might be a simple and inexpensive means in agriculture to increase soil moisture and OC that benefits farmers as well as reducing atmospheric CO_2.

Table 4.6 Comparison of soil fertility status before and after application of balanced fertilization and straw residue management on black gram grown after rice in Daik U Township

Treatment	pH water (1:1.25)	Organic Carbon (%)	Total N(%)	Availiable P (Bray) ppm	Available K mg kg^{-1}	CEC (meq/ 100 g soil)
Before	4.34 (0.03)	0.85 (0.03)	0.12 (0.01)	7.37 (0.02)	5.44 (0.02)	5.05 (0.04)
M_0F_0	5.24 (0.03)	0.82 (0.03)	0.11 (0.01)	5.98 (0.03)	3.69 (0.01)	6.07 (0.04)
M_0F_1	5.92 (1.76)	0.74 (0.03)	0.11 (0.01)	6.75 (0.04)	5.15 (0.03)	6.31 (0.02)
M_0F_2	5.27 (0.02)	0.65 (0.04)	0.10 (0.01)	6.47 (0.02)	6.67 (0.02)	6.04 (0.02)
M_0F_3	5.37 (0.02)	0.73 (0.02)	0.11 (0.01)	6.06 (0.03)	6.50 (0.02)	6.46 (0.03)
M_0F_4	5.32 (0.03)	0.66 (0.02)	0.11 (0.01)	6.91 (0.03)	6.51 (0.04)	5.81 (0.04)
M_1F_0	5.55 (0.03)	0.94 (0.03)	0.13 (0.01)	7.88 (0.03)	4.30 (0.04)	6.76 (0.03)
M_1F_1	4.82 (0.27)	0.93 (0.02)	0.13 (0.01)	7.82 (0.03)	7.35 (0.04)	6.043 (0.042)
M_1F_2	5.12 (0.03)	0.94 (0.02)	0.14 (0.01)	8.71 (0.02)	7.52 (0.02)	5.44 (0.01)
M_1F_3	5.04 (0.04)	0.93 (0.02)	0.13 (0.01)	10.13 (0.02)	9.72 (0.03)	6.11 (0.02)
M_1F_4	4.62 (0.03)	0.99 (0.04)	0.14 (0.01)	7.94 (0.02)	6.12 (0.04)	5.51 (0.02)

Numbers in the parentheses means standard deviation.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.1.3 Changes in total nitrogen

Total nitrogen content in soils with mulching and balanced fertilization was gained while those in soils without mulching applied with balanced fertilizers were depleted. In the study of Lutaladio et al. (1992), it was observed that increase of soil pH, soil organic carbon, total nitrogen, available phosphorus and exchangeable potassium, calcium and magnesium were increased as a result of increase in organic matter with continuous application of mulch for 3 years. Similarly, this study point out that increase in organic matter resulted out the increase in total nitrogen content. Smith et al. (1989) stated that returning plant residue to the soil is an effective method for sustaining soil organic matter concentration, enhancing biological activities, improving physical properties and increasing nutrient availabilities.

4.2.1.4 Changes in available phosphorus (P)

It was observed that changes of available P due to mulching with balanced fertilization were similar to the changes of total N in this study. Decline in available P in unmulched plots could probably be a result of plant uptake and P fixation even though applying balanced fertilization. This result was supported by Lal et al. (1980). In their study, available phosphorus was significantly affected by mulching.

4.2.1.5 Changes of available potassium (K)

In this study, available K due to mulching was not significantly changed. However, it contents in soils with control (no mulch without any chemical fertilizer), no mulch with urea fertilization and mulching with no chemical fertilization were significantly reduced when compared with soil before conducting experiment. The highest improvement of available K (9.72) was observed in soils with mulching and application of N, P and K fertilizers. Amarasiri and Wickremasinghe (1977) stated that rice straw contains 1.1 to 3.7 percent K which is water-soluble and is readily available to crop through soil and mulching increased the availability of K and P (Medcalf 1956).

4.2.1.6 Changes of cation exchangeable capacity (CEC)

In this study, CEC of all soils were benefited when compared with the soil before conducting experiment even though it was control soil. However, it was found that CEC values of most soils showed under the standard condition (low and very low). Duxbury et al. (1989) noted that most of the CEC in their studied soils were associated with SOM and Asadu et al. (1997) specifically indicated that SOM content could account for about 60% of the effective CEC of the soils with naturally low in organic matter and CEC.

4.2.2 Growth parameter

4.2.2.1 Plant height

The plant height was measured at 10 days interval from 10 to 80 days after sowing (DAS). The effect of rice straw mulching on plant height (cm) is presented in (Table 4.7). It was observed that there was the highly significant difference on the plant height ($Pr < 0.001$) level in all growth stages. Under the application of rice straw mulching (M_1), the plant height of black gram (7.29 cm) at 10 DAS was progressively increased to (26.62 cm) at 80 DAS. The result was similar with the findings of Bunna et al. (2011) who observed that effect of mulching on mungbean showed increased crop growth due to higher soil water content. This might be related increased infiltration and reduced soil evaporation of water.

Effect of balanced fertilizers management on plant height was observed in (Table 4.7). Plant height in all balanced fertilizers treatments was progressively increased from 10 DAS to 80 DAS. Statistically, there was a highly significant difference on the plant height in all growth stages from 30 DAS except 60 DAS at 5% level. At 80 DAS, the maximum plant height was observed in F_2 (26.96 cm) which was statistically similar with the plant height of F_4 fertilizers (26.67 cm) and followed by the plant height of F_3 (25.78 cm). The minimum plant height was observed in F_0 (18.43 cm). Similar result was found by Krasilnikoff et al. (2003) who stated that application of phosphorus fertilizer increased plant height. This might be attributed to the fact that phosphorus is required in large quantities in shoot and root tips where is high and cell division is rapid. Ndakidemi and Dakora (2007) and Hussain (1994) found that there was a significantly higher in plant height in mungbean crop when fertilized NPK. In addition, Bhattacharya et al. (2004) reported that application of 20 kg N, 40 kg P_2O_5, 40 kg K_2O and 1kg ammonium molybdate per hectare produced significantly higher plant height.

There was no interaction effect on plant height between balanced fertilizers and rice straw mulching methods at all growth stages. This result indicated that the rice straw mulching was not affected by balanced fertilizers application on plant height of black gram. According to results, the combination of balanced fertilizer and rice straw mulching on plant height trends were more curvy than that without mulching (Figure 4.11). Here, the nearly curve shapes of other treatment under without mulching were seen in this study. The effect of straw mulching (M_1) on plant height was compared to without mulching. In combination of balanced fertilizers and straw mulch, the highest plant height (30.60 cm and 29.90 cm) were observed in M_1F_4; NPKMo with rice straw mulching and M_1F_2; NP with rice straw mulching and the lowest plant height (16.20 cm and 18.76 cm) were observed in M_0F_0; non fertilizer application with no straw mulching and M_0F_1; N fertilizer with no straw mulching.

Table 4.7 Mean effect of balanced fertilizers and straw residue management on plant height of black gram during winter season, 2015 (Daik U Township)

Treatment	Plant height (cm)							
	10DAS	**20DAS**	**30DAS**	**40DAS**	**50DAS**	**60DAS**	**70DAS**	**80DAS**
Mulching (M)								
No Straw Cover (M_0)	4.57 b	6.23 b	9.63 b	12.29 b	15.14 b	17.51 b	19.88 b	21.09 b
Rice Straw Cover (M_1)	7.29 a	9.18 a	13.19 a	17.15 a	21.25 a	23.47 a	25.05 a	26.62 a
$LSD_{0.05}$	0.51	0.82	0.69	1.15	0.88	2.71	1.62	2.22
Fertilizer (F)								
F_0 (control)	5.64	6.92	9.78 b	11.80 b	14.41 c	16.02 b	16.59 c	18.43 b
F_1 (N)	5.86	6.85	10.38 b	12.00 b	15.07 c	18.78 ab	19.68 b	21.44 b
F_2 (NP)	6.17	8.52	11.97 a	16.92 a	21.47 a	22.87 a	26.50 a	26.96 a
F_3 (NPK)	6.15	8.40	12.35 a	15.97 a	19.25 b	22.20 a	24.59 a	25.78 a
F_4 (NPKMo)	5.84	7.83	12.58 a	16.93 a	20.78 a	22.60 a	24.98 a	26.67 a
$LSD_{0.05}$	0.80	1.30	1.09	1.82	1.39	4.28	2.56	3.51
Pr >F								
Mulching (M)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0001
Fertilizer (F)	0.5989	0.0348	0.0001	<0.0001	<0.0001	0.0126	<0.0001	0.0002
M× F	0.9716	0.3469	0.2224	0.0031	0.0028	0.2417	0.2741	0.8086
CV (%)	11.21	13.91	7.89	10.21	6.30	17.23	9.38	12.13

Means followed by the same letter within the column are not significantly different at LSD test 5% level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1}) F_0 = non fertilizer application,
F_1= 14- 0-0 NPK kg ha^{-1}, F_2= 14-19-0 NPK kg ha^{-1} F_3 = 14-19-32 NPK kg ha^{-1}, F_4 =14-19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

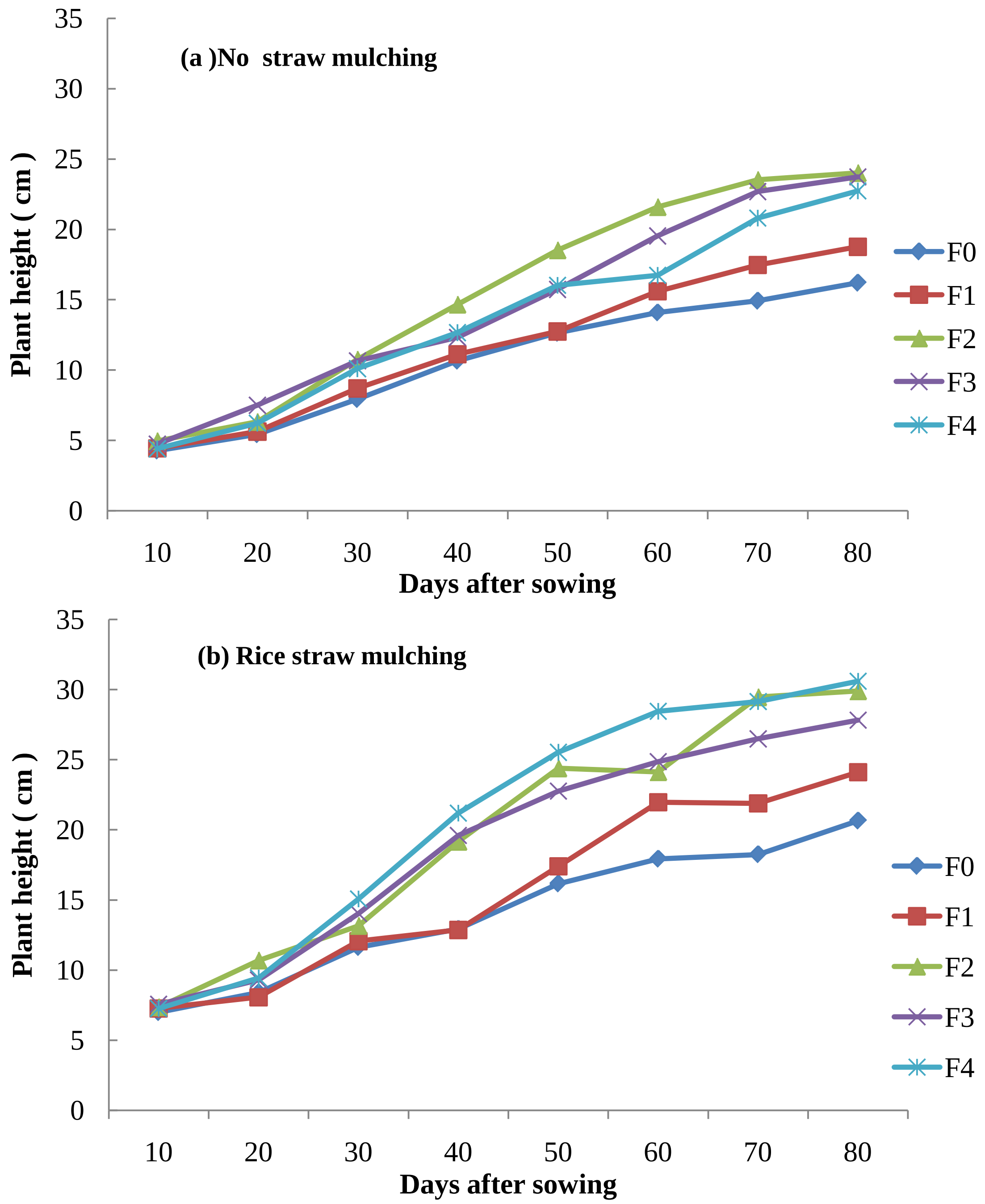


Figure 4.11 Mean comparison of plant height (a) no straw mulching (b) rice straw mulching as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14- 0- 0 NPK kg ha^{-1}, F_2= 14- 19- 0 NPK kg ha^{-1}

F_3= 14- 19- 32 NPK kg ha^{-1}, F_4 =14- 19- 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.3 Yield and yield components parameters

4.2.3.1 Seed yield

The seed yields (average) as affected by rice straw mulching methods are shown in (Table 4.8). It was observed that the effect of mulching on seed yield was highly significantly different at ($Pr < 0.001$). The seed yield (947.71 kg ha^{-1}) of rice straw mulching (M_1) was significantly higher than that (643.15 kg ha^{-1}) produced by without mulching (M_0). These results were supported by Chen et al. (2015). In their results, the plastic film combined with straw mulch showed more grain yield of wheat in tableland by providing sufficient soil water supply due to decreased soil water loss via evaporation. The reason of such an increase in yield under mulching with rice straw was that the ability of mulch caused to decrease soil temperature, enhance nutrient availability and increase root growth (Haque et al. 2003).

There was a significant difference on seed yield as affected by balanced fertilizers at 0.05 levels and are presented in (Table 4.8). The seed yield (663.58 kg ha^{-1}) produced by $F_{1;}$ N fertilizer was numerically higher than that (564.2 kg ha^{-1}) of control F_0; non-fertilizer application treatment due to starter nitrogen. But these were not statistically different. The maximum seed yield (963.22 kg ha^{-1}) was obtained from F_3; NPK that was statistically similar to F_4; NPKMo fertilizers (918.21 kg ha^{-1}) and then F_2; NP fertilizers (867.95 kg ha^{-1}) was followed. The response of F_2; NP fertilizers increased 31 % seed yield over F_1; N fertilizer and the response of F_3; NPK fertilizers increased 11 % seed yield over F_2; NP fertilizer. This study showed that application of phosphorus fertilizer increased the seed yield depending on the tested soil pH (4.34) with low available P. In concern with P- availability, Haruna (2011) and Condel et al. (2014) stated that acid soil had high P-fixation and Hussain (1994) and Kumar et al. (2014) discussed that application of 120 kg K_2O per hectare increased highest seed yield (1096 kg ha^{-1}) of mungbean. However, this study showed that the tested rate of ammonium molybdate fertilizer (0.0247 kg ha^{-1} treated with seeds) did not result in maximum yield of black gram. It was not agreed to Bhattacharya et al. (2004)'s observation. In their report, they showed that 20 kg N, 40 kg P_2O_5, 40 kg K_2O and 1 kg ammonium molybdate per hectare resulted highest grain yield of black gram and green gram.

There was no interaction effect due to balanced fertilizer application and rice straw mulching on seed yield in this study. This result indicated that the response of seed yield due to rice straw mulching was not affected by balanced fertilizer application.

From the combined effects of balanced fertilizers and straw residue management as in (Figure 4.12), the maximum seed yields (1273.90 kg ha^{-1}) was obtained from M_1F_3; NPK with straw cover. M_1F_4; NPKMo with rice straw mulching produced (1088.30 kg ha^{-1}) of seed yield. Then M_1F_2; NP and straw mulching produced 1050.50 kg ha^{-1}. The minimum seed yield was observed from M_0F_0 ; non fertilizer application with no straw mulching (526.30 kg ha^{-1}). The seed yield of M_0F_1; N fertilizer without rice straw mulching was 603.50 kg ha^{-1}. In this case, the effect of rice straw mulching obtained higher seed yield and the combination of balanced fertilizers increased seed yield of black gram. Application of N fertilizer only did not produce higher seed yield.

Table 4.8 Mean effect of balanced fertilizers and straw residue management on yield and yield components of black gram during winter season, 2015 (Daik U Township)

Treatment	Seed yield ($kg\ ha^{-1}$)	Pods $plant^{-1}$ no.	Seeds pod^{-1} no.	100 seed weight (g)
Mulching (M)				
No straw mulching(M_0)	643.15 b	8.53 b	6.34	5.69
Rice straw mulching (M_1)	947.71 a	11.46 a	6.50	5.84
LSD0.05	130.77	1.33	0.26	0.16
Fertilizer (F)				
F_o (control)	564.20 c	7.62 b	6.40	5.55
F_1 (N)	663.58 bc	8.87 b	6.12	5.73
F_2 (NP)	867.95 ab	11.17 a	6.45	5.81
F_3 (NPK)	963.22 a	11.27 a	6.65	5.88
F_4 (NPKMo)	918.21 a	11.05 a	6.48	5.83
LSD0.05	206.77	2.10	0.41	0.25
Pr> F				
Mulching (M)	0.0001	0.0002	0.2078	0.0655
Fertilizer (F)	0.0026	0.0044	0.1371	0.0968
Mulching× Fertilizer	0.0814	0.2817	0.9730	0.2521
CV (%)	21.43	17.30	5.22	3.64

Means followed by the same letter within the column are not significantly different at LSD test 5% Level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.3.2 Number of pods per plant

The number of pods per plant as affected by rice straw mulching methods are presented in (Table 4.8). There was a highly significant difference due to mulching with rice straw ($Pr < 0.001$). The maximum number of pods per plant (11.46) was resulted in rice straw mulching (M_1) and the minimum number of pods per plant (8.53) in no straw mulching (M_0). In this case, adequate soil water storage in rice straw mulching might produce higher number of pods per plant. In addition, Musick et al. (1994) explained that sufficient soil water supply was beneficial to tiller growth and spike differentiation of the winter wheat.

Effect of balanced fertilizers management on number of pods per plant was significantly different at 0.05 levels as in (Table 4.8). The application of N fertilizer only (F_1) gave a slightly increase in pod number per plant (8.87) which was statistically similar in F_0; non-fertilizer application (7.62). The highest number of pods per plant (11.27) was resulted in F_3; NPK fertilizers that was statistically similar F_2; NP fertilizers (11.17) and F_4; NPKMo fertilizers (11.05). This study recognized that application of phosphorus fertilizer increased number of pods per plant due to tested soil with low available P range. The effect of potassium application slightly increased the number of pod per plant. The results of present study showed that there was no effect of ammonium molybdate (0.0247 kg ha^{-1} with seeds treatment) on number of pods of plant. Osodeke (2005) discussed that phosphorus (P), among the most needed elements for crop production in tropical soils are generally P-deficient. As Haruna and Aliyu (2011) statement about P, it was understood that P stimulates growth, initiates nodule formation as well as influences the efficiency of the rhizobium-legume symbiosis. Potassium application increased the availability of nitrogen and phosphorus (Sahai 2004) which resulted in better plant growth and more number of branches per plant.

No interaction was observed between balanced fertilizers and rice straw mulching on number of pods per plant. This result indicated that the response of the number of pods per plant due to rice straw mulching was not affected by balanced fertilizers application.
From the combined effects with balanced fertilizer application and straw residue management as in (Figure 4.13), the maximum number of pods per plant (13.70) was resulted in M_1F_2; NP fertilizers with mulching. The minimum number of pods per plant (7.23) was observed in $M_0F_{0;}$ non fertilizer application with no straw mulching. In this case, The response of pod number (13.7) by the combination of N and P fertilizer with

rice straw mulching (M_1F_2) was higher than (8.63) M_0F_2; NP fertilizers with non-mulching and (8.0) M_1F_0; non fertilizer application with rice straw mulching. This results indicated that the effect of the rice straw mulching increased higher number of pods per plant and application of balanced fertilizers also increased higher number of pods per plant of black gram as well.

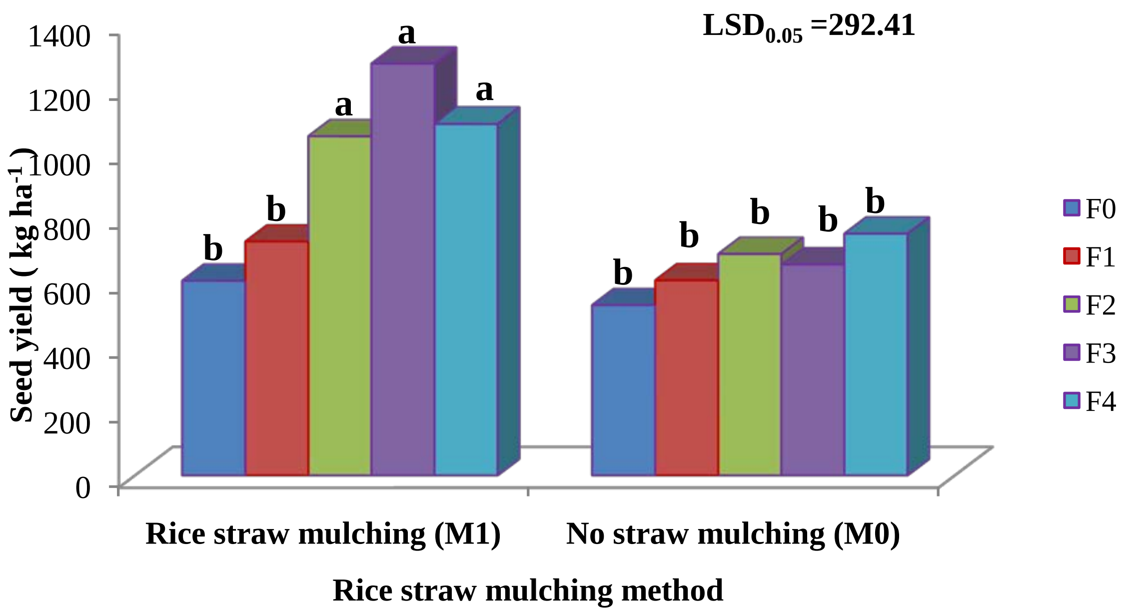


Figure 4.12 **Mean comparison of seed yield as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)**

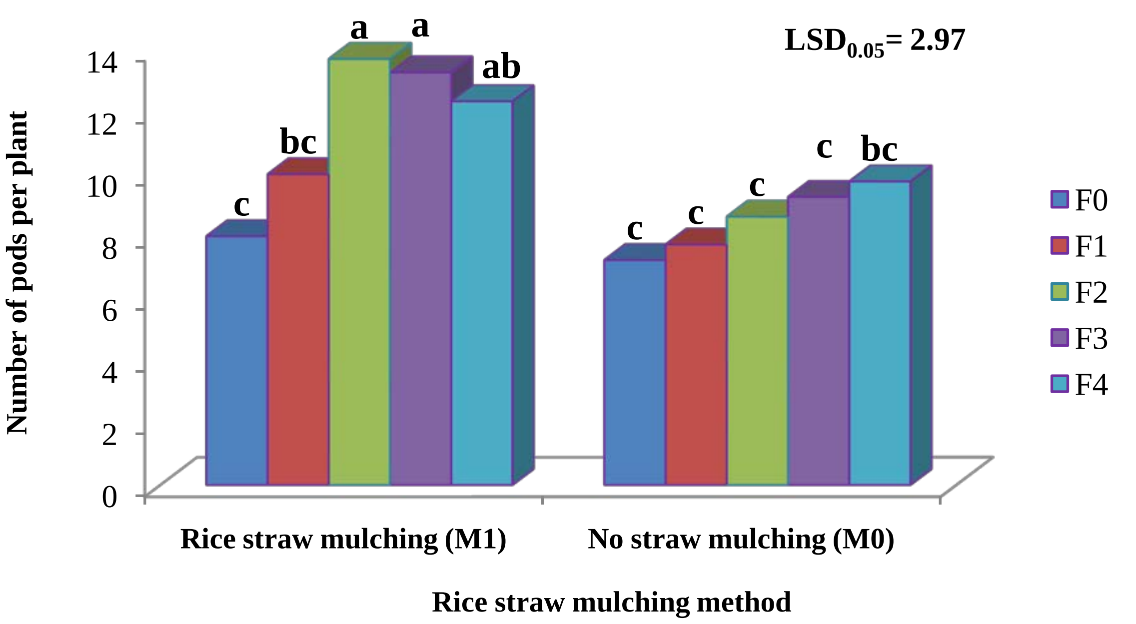


Figure 4.13 **Mean comparison of number of pods per plant as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.3.3 Number of seeds per pod

Influence of mulching with rice straw on number of seeds per pod is presented in (Table 4.8). There was not significantly different in number of seeds per pod among rice straw mulching methods. This might be related with crop water use of black gram in which water use with straw mulching (152.01 mm) and with no straw mulching (151.48 mm) that were not significant different. Pal et al. (1991) noted that water requirement of black gram were found at branching, flowering and pod development stages.

There was not significantly different in number of seeds per pod as influenced by balanced fertilizer management in (Table 4.8) although number of pods per plant were significant different. Numerically, it was observed that the highest number of seeds per pod (6.65) was produced by F_3; NPK fertilizers and the lowest number of seeds per pod (6.12) by F_1; N fertilizer respectively. When a look to the effect of F_2; NP fertilizers on seed numbers, it showed (6.45). In the study of Nkaa et al. (2014) on cowpea, the application of 60 kg ha^{-1} phosphorus level gave highly significantly difference in number of seeds per pod compared with application of 0 kg ha^{-1}, 20 kg ha^{-1} and 40 kg ha^{-1} phosphorus levels that were similar number of seeds per pod. The reason of increased in seed numbers produced by application of complete fertilizers might be related to test variety, low soil pH and low available P. (discussed in 4.2.3.2 section)

There was no significant difference on number of seeds per pod between balanced fertilizers and straw residue management in (Table 4.8). This result indicated that response of number of seeds per pod due to rice straw mulching was not affected by balanced fertilizers application.

In the combined effects with balanced fertilizers and straw residue management as (Figure 4.14), the maximum number of seeds per pod (6.70) was observed in M_1F_3; NPK fertilizers with rice straw mulching and the minimum number of seeds per pod (6.10) was resulted in M_0F_1; N fertilizer with no straw mulching. The higher number of seeds per pods were produced from M_0F_3; NPK fertilizers without rice straw mulching (6.60), M_1F_4; NPKMo with rice straw mulching (6.37) and M_0F_3; NPK with no straw mulching (6.37). The result showed that straw mulching method increased number of seeds per pod and the combination of balanced fertilizers increased number of seeds per pod of black gram.

4.2.3.4 Hundred seed weight (g)

The mean values of 100 seed weight as affected by mulching with rice straw are presented in (Table 4.8). There was not significantly different in 100 seed weight on black gram (discussed in 4.2.3.3 section)

The mean values of 100 seed weight as affected by balanced fertilizers management are recorded in (Table 4.8). It was observed that in test soil, low pH (4.34) and Low CEC (5.05), there was no significant difference on 100 seed weight on test variety although effect of balanced fertilizers significantly increased on seed yield of black gram.

There was no interaction effect on 100 seed weight between balanced fertilizers and straw mulching. From the combined effects of balanced fertilizer application and straw residue methods as in (Figure 4.15), 100 seed weight in all combination of treatments were similar but they were higher than M_0F_0; non fertilizers application with no straw mulching.

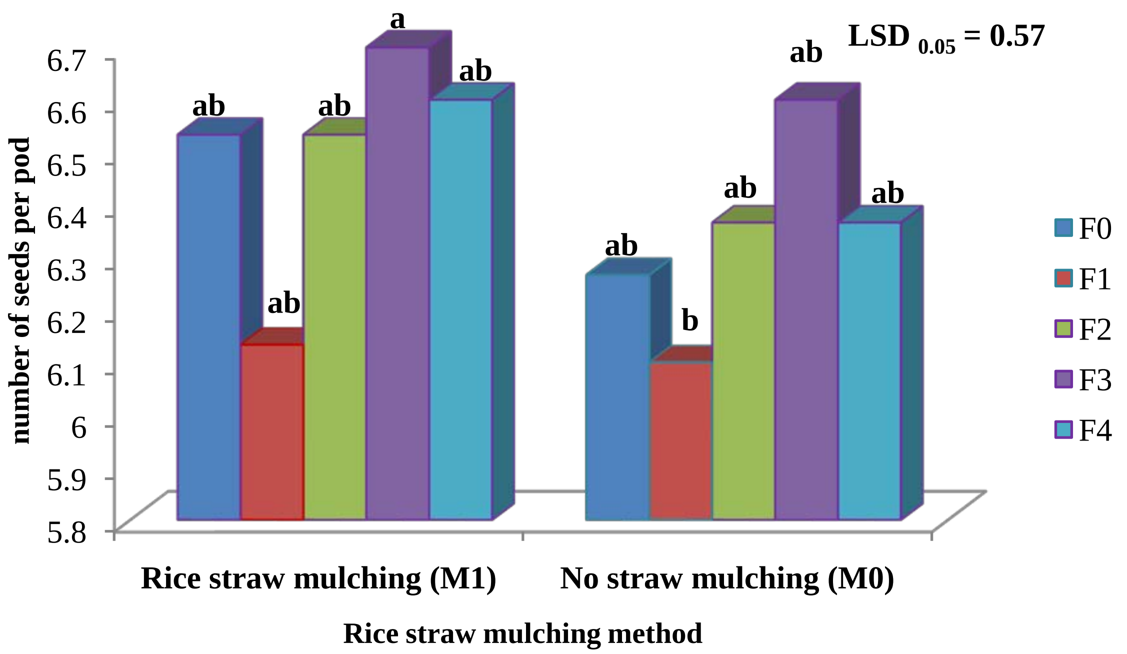


Figure 4.14 Mean comparison of number of seeds per pod as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)

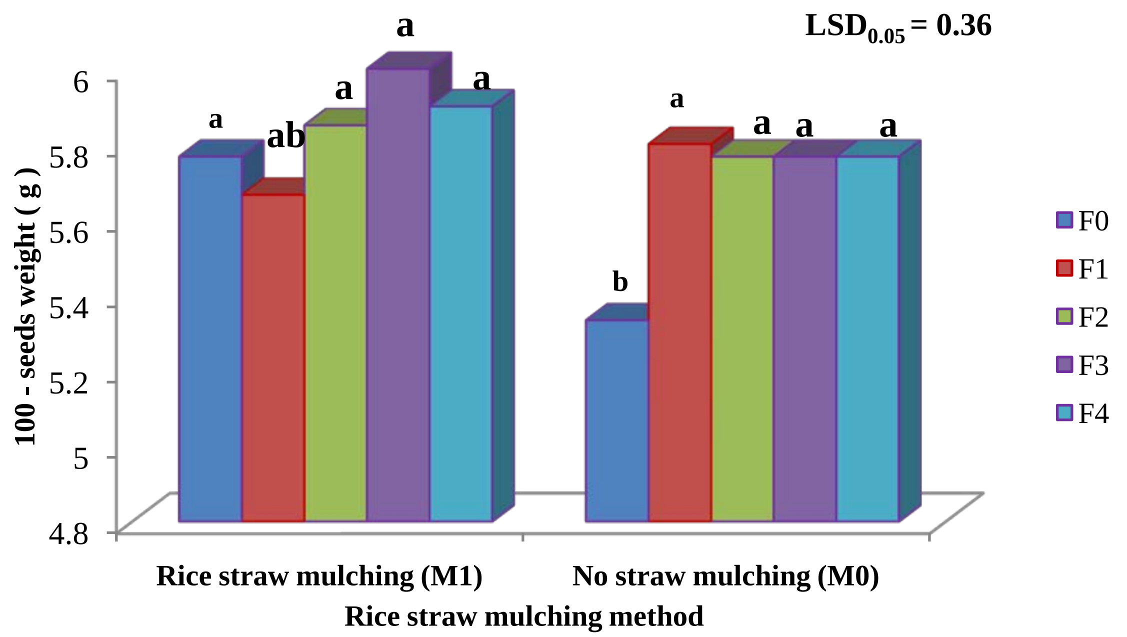


Figure 4.15 Mean comparison of 100 seed weight as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.3.5 Total dry matter content (TDM)

The significant difference in total dry matter (TDM) was observed among rice straw mulching methods at harvest (Pr < 0.001) (Table 4.9). The maximum total dry matter (3401.10 kg ha^{-1}) was recorded in rice straw mulching and minimum total dry matter (2697.7 kg ha^{-1}) in non-rice straw mulching. The result of present study was in similar with the results of Su et al. (2014) who observed that the effect of straw mulching on dry matter accumulation of oilseed rape was increased 31.1 % at maturity stage. This might be due to the increase in the soil water availability and reduction in soil temperature fluctuation by straw mulching. These two factors might have favored the development of root system thereby improved the ability of root system to absorb more water and nutrients. (Barber et al.1988).

There was significant difference on total dry matter as affected by balanced fertilizers at 0.01 levels (Table 4.9). Effect of F_1; N fertilizer (2620.10 kg ha^{-1}) on total dry matter was slightly higher than that of control F_0; non-fertilizer application (2380.30 kg ha^{-1}) but they were not statistically different. On the other hand, effect of F_2; NP fertilizers (3417.40 kg ha^{-1}) was significantly higher than that of F_1; N fertilizer and F_0; non-fertilizer application. The highest total dry matter was resulted in F_3; NPK fertilizers (3506.40 kg ha^{-1}) that was statistically similar with F_2; NP fertilizers (3417.40 kg ha^{-1}) and F_4; NPKMo fertilizers (3322.90 kg ha^{-1}). Gavito and Miller (1998) who reported that enhanced early-season P nutrition in corn increased the dry matter partitioning to the grain at later development stages. The significant response of the measured yield characters of cowpea to phosphorus application could be attributed to the role of phosphorus in seed formation and grain filling (Haruna 2011).

Interaction on total dry matter was not observed between balanced fertilizers and rice straw cover methods. From the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.16), the maximum total dry matter was resulted in M_1F_3; NPK with rice straw mulching (4101.00 kg ha^{-1}). M_1F_2; NP with rice straw mulching produced (3940.20 kg ha^{-1}) and M_1F_4; NPKMo with rice straw mulching resulted (3824.40 kg ha^{-1}) among all treatments. The effect of M_1F_2; NP fertilizers with rice straw mulching (3940.20 kg ha^{-1}) obtained higher total dry matter than M_0F_2; NP with no straw mulching (2894.70 kg ha^{-1}) and M_1F_1; N fertilizer with rice straw mulching (2757.60 kg ha^{-1}). This results showed the effect of rice straw mulching produced higher total dry matter and the effect of balanced fertilizers application increased total dry matter of black gram as well.

4.2.3.6 Harvest index (HI)

Harvest index (HI) is the ratio of economic yield to biological yield and productive efficiency of a crop measured.

Mean values of HI as affected by balanced fertilizers and rice straw mulching methods are presented in (Table 4.9). There was significantly different in HI at 0.05 level due to rice straw mulching. The rice straw mulching (3 ton ha^{-1}) produced higher value of HI (0.28) compared to without mulching. Its harvest index was (0.24). Thus, favorable soil moisture under rice straw mulching during the growing stages was the reason for higher seed yield and harvest index of black gram.

There was no significant difference on harvest index (HI) among balanced fertilizers application. In this study, fertilizer applications increased the total dry matter together with promoted growth and yield parameters. In this case, phosphorus also helps in better root growth resulted that the plant extract more nutrient and moisture from deeper soil layer leading to better growth and development (Kanwar et al. 2013).

No interaction was observed between balanced fertilizers and rice straw cover method. From the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.17), M_1F_3; NPK with rice straw mulching treatment obtained higher harvest index (0.30) than M_0F_3; NPK fertilizers without rice straw mulching (0.23), and M_1F_0; non-fertilizer application with rice straw mulching (0.26). Thus, in the black gram production in Daik U region, mulching with rice straw could increase its harvest index.

Table 4.9 Mean effect of balanced fertilizers and straw residue management on total dry matter production and harvest index of black gram during winter season, 2015 (Daik U Township)

Treatment	Total dry matter ($kg\ ha^{-1}$)	Harvest Index (HI)
Mulching (C)		
No straw mulching(M_0)	2697.70 b	0.24 b
Rice straw mulching (M_1)	3401.10 a	0.28 a
LSD0.05	405.65	0.03
Fertilizer (N)		
F_0 (control)	2380.30 b	0.24
F_1 (N)	2620.10 b	0.25
F_2 (NP)	3417.40 a	0.25
F_3 (NPK)	3506.40 a	0.27
F_4 (NPKMo)	3322.90 a	0.28
LSD0.05	641.40	0.05
Pr> F		
Mulching (M)	0.0019	0.0276
Fertilizer (F)	0.0040	0.5140
Mulching× Fertilizer	0.2453	0.7756
CV (%)	17.34	16.3

Means followed by the same letter within the column are not significantly different at LSD test 5% level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

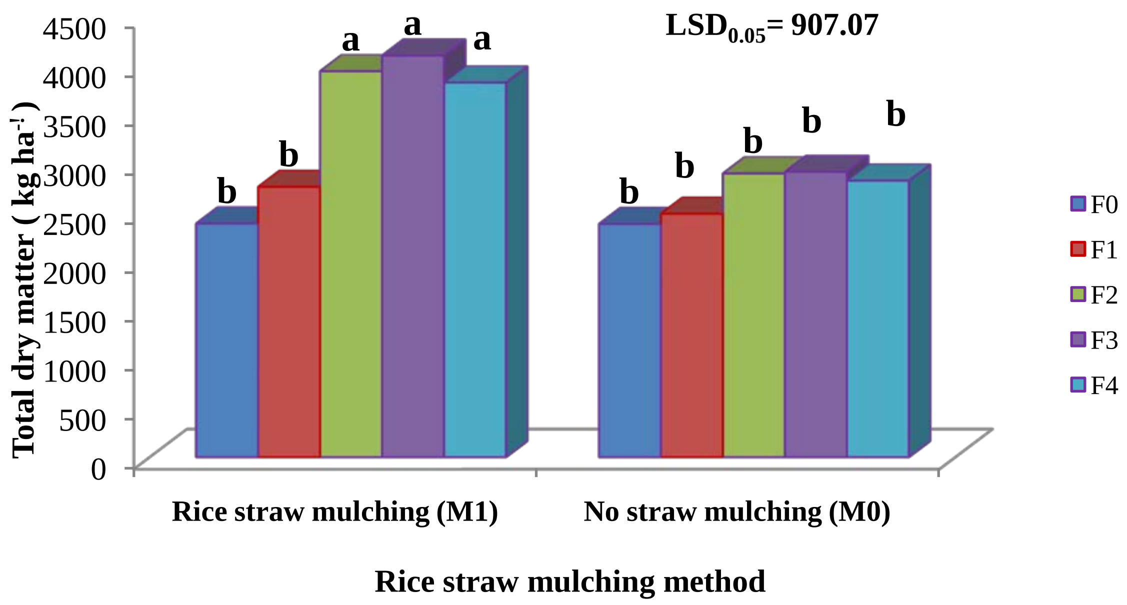


Figure 4.16 Mean comparison of total dry matter as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)

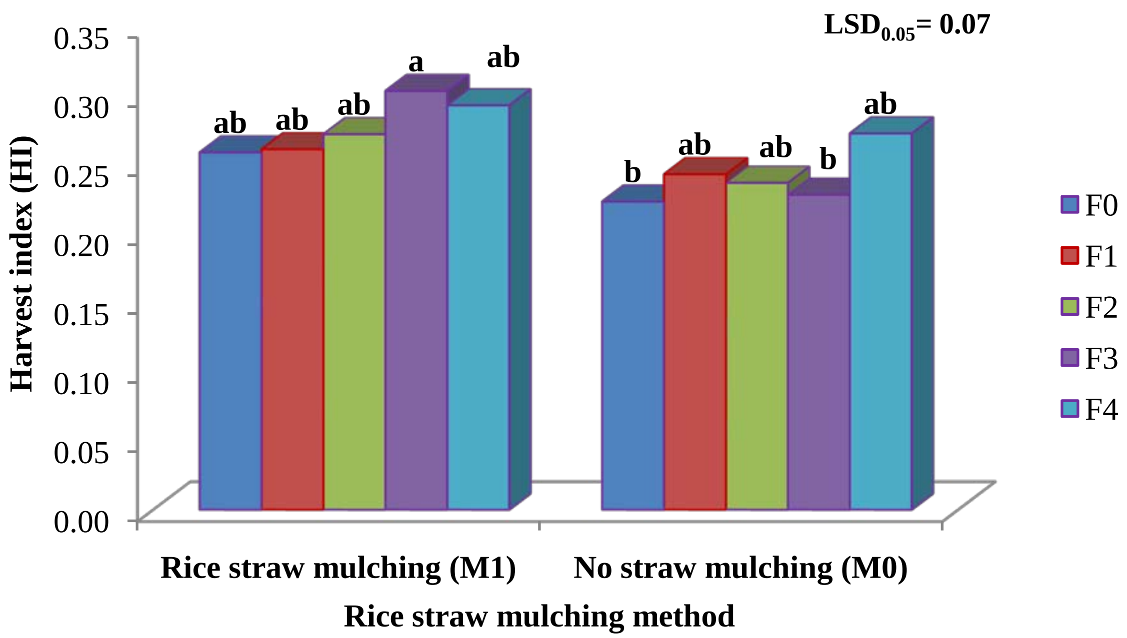


Figure 4.17 Mean comparison of harvest index as affected by balanced fertilizers and straw residue management on black gram during winter season, 2015 (Daik U Township)

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.4 Changes in soil water status

Figure 4.18 shows the changes of soil water status from the beginning to the end of crop grown in Daik U, Bago region. During the crop growth stages, it was found that higher amount of water stored in plots with mulching than those under without mulching. The trend was similar to Ma U Bin. Moreover, the residual soil moisture at the end of crop growth stage was also higher in soils with mulching than those under without mulching. The maximum amount of soil water could be stored in M_1F_3 (16.23 mm) and the minimum amount was occurred in M_0F_1 (11.32 mm). Even though there were applied with chemical fertilizers in mulching plots, residual soil moisture in such plots was still high. It meant that mulching conserves soil moisture significantly and that supplies crop water availability, resulting in the higher crop growth and yield (Zhang et al. 2005).

4.2.5 Total water use (mm)

The mean value of total soil water use as affected by balanced fertilizers and straw residue management are presented in (Table 4.10). Although the effect of different types of rice straw mulching on total water use was not statistically different, the total water use by rice straw mulching (3 ton ha^{-1}) (M_1) was 152.01 mm and that without mulching (M_0) was 151.48 mm. This result indicated that change of soil water use might depend on low organic matter content of soil (0.853%) and higher yield of mulching treatment. Additions of organic materials to soil increases soil water-holding capacity of soil (Fan et al. 2005). According to Jalota and Prihar (1998), higher the water use by crops, the higher the yield becomes.

Total water use as affected by balanced fertilizers application was not statistically different. Numerically, the highest total water use (154.11 mm) was resulted from F_2; NP fertilizers and the lowest (149.35 mm) was obtained from F_3; NPK fertilizer.

There was no interaction between balanced fertilizers and rice straw mulching as in (Table 4.10). From the combined effects of balanced fertilizers and rice straw mulching (Figure 4.19), the maximum total water use (154.66 mm) was observed from M_0F_2; NP with no rice straw mulching. The minimum water use (149.12 mm) was recorded from M_0F_3; NPK with no straw mulching. The results are in line with Singh and Bhushan (1980) who found that addition of P to chickpea increased yield, water use and WUE. Zeng et al. (1999) stated that slow downward movement of applied K may be partially attributed to net upward flux of soil water in the soil profile as a result of high evapotranspiration in summer.

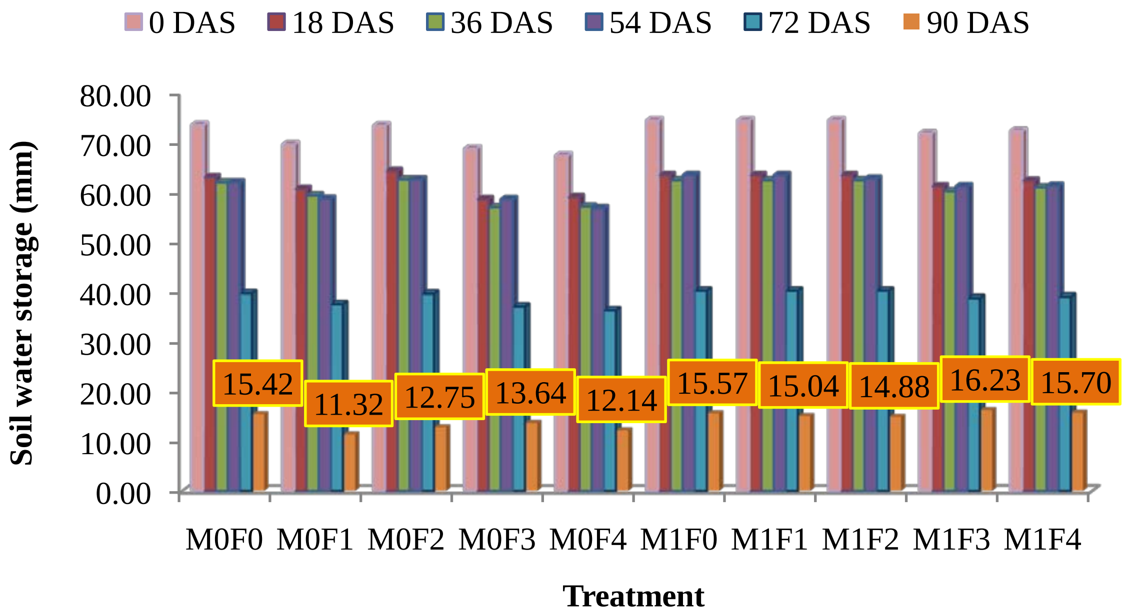


Figure 4.18 Changes of soil water status on black gram grown after rice affected by balanced fertilization and straw residue management in Daik U township

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

Table 4.10 Mean effect of balanced fertilizers and straw residue management on total water use and water use efficiency of black gram during winter season, 2015 (Daik U Township)

Treatment	Total Water Use (mm)	Water Use efficiency (kg $ha^{-1}mm^{-1}$)
Mulching (M)		
No straw mulching(M_0)	151.48	4.25 b
Rice straw mulching (M_1)	152.01	6.28 a
$LSD_{0.05}$	2.25	0.98
Fertilizer (F)		
F_0 (control)	152.49 ab	3.70 c
F_1 (N)	152.86 ab	4.35 bc
F_2 (NP)	154.11 a	5.64 ab
F_3 (NPK)	149.35 b	6.52 a
F_4 (NPKMo)	149.93 b	6.12 a
$LSD_{0.05}$	3.55	1.55
Pr> F		
Mulching (M)	0.6267	0.0004
Fertilizer (F)	0.0526	0.0056
Mulching× Fertilizer	0.9528	0.1219
CV (%)	1.93	24.35

Means followed by the same letter within the column are not significantly different at LSD test 5% level.

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

4.2.6 Water use efficiency

The mean values of water use efficiency of black gram as affected by different straw mulching are presented in (Table 4.10). There was significant difference among different types of rice straw mulching at 0.01 level. The maximum water use efficiency (6.28 kg ha^{-1} mm^{-1}) was recorded in rice straw mulching and the minimum (4.25 kg ha^{-1} mm^{-1}) in no straw mulching. The results are in conformity to the findings of Jat and Gautam (2001) who reported that straw mulch and straw + kaolin application to pearl millet was superior to all other treatments in terms of yield, consumptive use and water use efficiency of rain fed pearl millet.

In (Table 4.10), the mean values of water use efficiency as affected by balanced fertilizers application was statistically different at 0.05 level. The maximum water use efficiency (6.52 kg ha^{-1} mm^{-1}) was observed in F_3; NPK fertilizers that is not statistically different from F_4; NPKMo fertilizers (6.12 kg ha^{-1} mm^{-1}) and F_2; NP fertilizers (5.64 kg ha^{-1} mm^{-1}) was followed these treatments. Moreover, water use efficiency of F_1; N fertilizer (4.35 kg ha^{-1} mm^{-1}) was higher than F_0; non fertilizer application (3.70 kg ha^{-1} mm^{-1}). Similarly, Tetarwal and Rana (2006) reported that the highest water use efficiency, consumptive use and rate of moisture use were found in the treatments of 80 kg N + 40 kg P_2O_5 ha^{-1} followed by 40 kg N + 20 kg P_2O_5 ha^{-1} as the more equivalent yield was corresponding to increase in consumptive use of water with high fertility level.

There was no interaction between balanced fertilizers and rice straw mulching as in (Table 4.10). The results indicated that the response of water use efficiency by rice straw mulching was not influenced by balanced fertilizers. In the combined effects of balanced fertilizers and rice straw mulching as in (Figure 4.20), the maximum water use efficiency (8.66 kg ha^{-1} mm^{-1}) was obtained from M_1F_3; NPK with rice straw mulching. The minimum water use efficiency (3.46 kg ha^{-1} mm^{-1}) was resulted in M_0F_0; non-fertilizer application with no straw mulching. The results indicated that the effect of rice straw mulching produced higher water use efficiency and the balanced fertilizers increased water use efficiency of black gram as well.

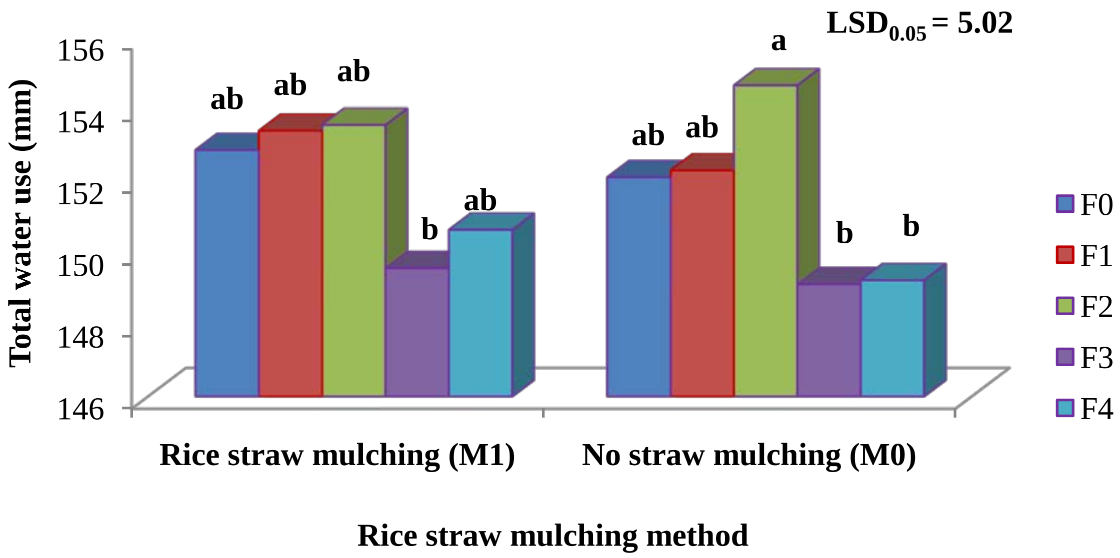


Figure 4.19 **Mean comparison of total water use of black gram as affected by balanced fertilizers and straw residue management during winter season, 2015 (Daik U Township)**

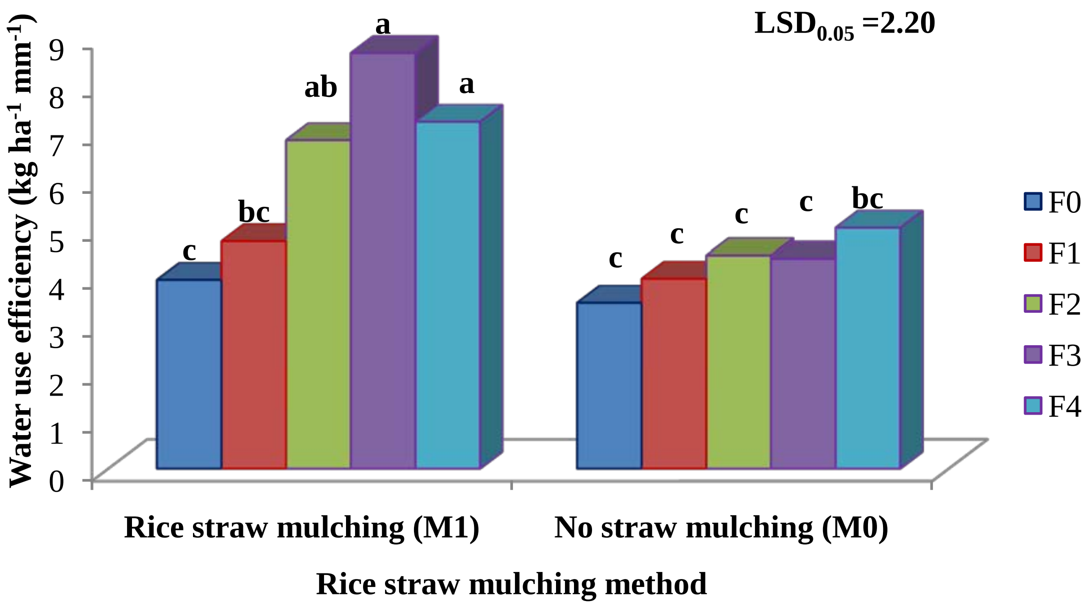


Figure 4.20 **Mean comparison of water use efficiency as affected by balanced fertilizers and straw residue management during winter season, 2015 (Daik U Township)**

M_0 = no mulching, M_1 = rice straw mulching (3 ton ha^{-1})

F_0 = non fertilizer application, F_1= 14 - 0 - 0 NPK kg ha^{-1}, F_2= 14 - 19 - 0 NPK kg ha^{-1}

F_3= 14 - 19 - 32 NPK kg ha^{-1}, F_4 =14 - 19 - 32 NPK plus 0.025 $(NH_4)_6Mo_7O_{24}.4H_2O$ kg ha^{-1}

CHAPTER V
CONCLUSION

The results of present study revealed the effect of balanced fertilizer and straw residue management on soil organic carbon and nitrogen, grain yield, total water use and water use efficiency of black gram during winter season, 2015 in Maubin Township, Ayeyarwaddy Division and Daik U Township, Bago Division.

Based on the results of experiment in Maubin township, changes of soil organic carbon was greatly influenced by balanced fertilizers and rice straw mulching method. Its changes varies from slightly decrease (9 %) in M_0F_1 to significantly increase to 61 % in M_1F_3. In terms of N changes, balanced fertilizers application and rice straw mulching has a great influence on increment of soil nitrogen as 11 % under M_1F_4 which produced the maximum seed yield (758.48 kg ha^{-1}) indicating the higher performance of agronomic characters. Similarly, grain yield, total water use, water use efficiency were greatly influenced by rice straw mulching method as well as by balanced fertilizer management. Growing of black gram by applying rice straw mulching method increased in yield to 32 %, decrease 3 mm in total water use and increased in water use efficiency to 34 %. As the results of balanced fertilizer application, the dosage of 14 - 19 - 32 NPK plus 0.025 ammonium molybdate (seed treated) kg ha^{-1} (F_4) could produce highest grain yield (677.86 kg ha^{-1}) increased to 28 %, total water use (152.77 mm) and water use efficiency (4.45kg ha^{-1} mm^{-1}) increased to 28 % over control. Moreover, more soil moisture (28.72 mm) was stored under balanced fertilizer application with rice straw mulching M_1F_2 than that without mulching at the end of crop. Under the same residual moisture content, the growths were greatly affected by mulching with balanced fertilizer application. Growth performance was the best in rice straw mulching with complete fertilizer application (M_1F_4). Thus, it can be concluded that application of 14- 19- 32 NPK plus 0.025 ammonium molybdate (seed treated) kg ha^{-1} (F_4) with rice straw mulching can improve soil fertility in term of soil organic carbon and soil total nitrogen, can give best growth performance and can in increase in yield and water use efficiency as well as can store much residual water.

As the results of experiment in Daik U Township, changes of soil organic carbon and total nitrogen were also influenced by balanced fertilizers and rice straw mulching method. Its changes varies from greatly decrease (22 %) in M_0F_4 to merely increase to 9 % in M_1F_3. In terms of N changes, balanced fertilizers application and rice straw mulching has a great influence on increment of soil nitrogen as 10 % under M_1F_3 which produced maximum seed yield (1273.90 kg ha^{-1}) with higher performance of agronomic characters. In addition, the rice straw mulching affected grain yield and water use efficiency of black gram. Growing of black gram by applying rice straw mulching increased in yield to 47 % and water use efficiency to 48 %. In application of balanced fertilizers, the dosage of 14 - 19 - 0 NPK kg ha^{-1} could produce higher yield (867.95 kg ha^{-1}), total water use (154.11 mm) and water use efficiency of black gram (5.64 kg ha^{-1} mm^{-1}). The dosage of 14 - 19 - 32 NPK kg ha^{-1} could produce highest yield (963.22 kg ha^{-1}) increased to 62 %, minimum water use (149.35 mm) and highest water use efficiency (6.52 kg ha^{-1} mm^{-1}) increased to 65 % over control. Moreover, more soil moisture (16.23 mm) was stored under balanced fertilizer application with rice straw mulching (M_1F_3) than that without mulching at the end of crop. Under the same residual moisture content, the growths were greatly affected by mulching with balanced fertilizer application. Better growth performances were shown in rice straw mulching with balanced fertilizer applications (M_1F_2, M_1F_3 and M_1F_4). Thus, it can be concluded that application of 14 - 19 - 32 NPK kg ha^{-1} (F_3) with rice straw mulching can improve soil fertility in term of soil organic carbon and soil total nitrogen and can in increase in yield and water use efficiency as well as can store much residual water.

Therefore, it could be recommended that mulching with rice straw in black gram cultivation in Maubin township and Daik U township is the appropriate management practice for improving yield, water use efficiency and residual soil moisture. Different fertilizer recommendations could be applied for both townships. According to residual soil moisture, it would be managed in further crop production with proper irrigation practice. In Daik U township, addition of organic matter could be applied to increase soil pH and water holding capacity of silt loam soil. Moreover, application of phosphorus fertilizer would increase the yield and WUE. Moreover, it is necessary to conduct the similar experiments on other regions in Myanmar to recommend the proper management practices locally.

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APPENDICES

Appendix 1 Character of Yezin-3 variety

Code No	P-11-30
Seedling Vigor	Intermediate
Hypocotyl colour	Dark purple
Growth habit	Erect
Growth pattern	Determinate
Raceme position	Intermediate
Days to flowering	32
Flowering period	Intermediate (flowering period 16-30 days)
No of pod bearing (no)	12.70
Days of 1st mature pods (days)	61
No of seeds per pod (no)	5.0
Seed color	Black
100-seeds weight (g)	4.3
Yield per plant (g)	2.92

Appendix 2 Combination effect of balanced fertilizers and straw residue management on plant height of blackgram during winter season, 2015 (Maubin Township)

Treatment	Plant height (cm)							
	10DAS	**20DAS**	**30DAS**	**40DAS**	**50DAS**	**60DAS**	**70DAS**	**80DAS**
M_0F_0	3.50 de	4.73 cd	5.30 de	6.37 bcd	7.73 d	10.18 b	11.75 e	12.57 e
M_0F_1	4.17 cde	4.43 d	5.50 de	6.10 cd	8.90 bcd	12.87 ab	14.40 bcde	15.19 de
M_0F_2	3.93 cde	4.53 d	4.57 e	7.63 abc	7.27 d	11.50 b	13.03 de	13.87 de
M_0F_3	3.90 cde	5.20 bcd	5.95 cd	7.45 bc	8.37 cd	11.77 b	13.30 cde	14.14 de
M_0F_4	3.33 e	4.43 d	4.60 e	4.87 d	6.90 d	11.37 b	11.53 e	13.05 e
M_1F_0	4.00 cde	5.20 bcd	5.60 de	7.17 bcd	8.70 bcd	11.60 b	15.74 abcd	16.64 cd
M_1F_1	4.23 cd	5.87 ab	6.95 bc	8.73 ab	11.48 abc	12.53 ab	15.92 abcd	18.56 bc
M_1F_2	4.67 bc	5.73 abc	7.64 ab	8.74 ab	12.68 a	13.45 ab	16.85 abc	19.90 ab
M_1F_3	5.50 ab	5.67 abc	7.33 ab	9.90 a	12.57 a	15.97 a	19.23 a	23.01 a
M_1F_4	5.71 a	6.44 a	8.50 a	10.03 a	12.33 ab	15.90 a	17.93 ab	21.60 ab
$LSD_{0.05}$	0.85	1.07	1.27	2.42	3.65	3.86	3.78	3.21
Pr > F	*	ns	*	ns	ns	ns	ns	ns
CV (%)	11.58	11.90	11.99	18.30	21.97	17.70	14.73	11.09

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level

* = significant at 5% level

ns = non-significant

Appendix 3 Combination effect of balanced fertilizers and straw residue management on plant height of black gram during winter season, 2015 (Daik U Township)

Treatment	Plant height (cm)							
	10DAS	**20DAS**	**30DAS**	**40DAS**	**50DAS**	**60DAS**	**70DAS**	**80DAS**
M_0F_0	4.28 b	5.43 e	7.93 g	10.67 c	12.65 e	14.10 e	14.92 e	16.20 e
M_0F_1	4.44 b	5.63 e	8.70 fg	11.13 c	12.75 e	15.60 de	17.47 de	18.76 de
M_0F_2	4.97 b	6.33 de	10.77 de	14.67 b	18.53 c	21.60 bcd	23.53 bc	24.02 bc
M_0F_3	4.74 b	7.50 cd	10.67 de	12.33 bc	15.73 d	19.53 bcde	22.69 c	23.73 bc
M_0F_4	4.41 b	6.23 de	10.10 ef	12.67 bc	16.03 d	16.73 cde	20.80 cd	22.73 cd
M_1F_0	6.99 a	8.40 bc	11.63 cde	12.93 bc	16.17 d	17.93 cde	18.25 de	20.65 cde
M_1F_1	7.27 a	8.07 bcd	12.07 cd	12.87 bc	17.40 cd	21.97 bc	21.89 c	24.11 bc
M_1F_2	7.37 a	10.70 a	13.17 bc	19.17 a	24.40 c	24.13 ab	29.47 a	29.90 a
M_1F_3	7.57 a	9.30 abc	14.03 ab	19.60 a	22.77 b	24.87 ab	26.49 ab	27.82 ab
M_1F_4	7.26 a	9.43 ab	15.07 a	21.20 a	25.53 a	28.47 a	29.15 a	30.60 a
$LSD_{0.05}$	1.14	1.84	1.55	2.58	1.97	6.06	3.61	4.96
Pr > F	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	11.21	13.91	7.89	10.21	6.30	17.23	9.38	12.13

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level
* = significant at 5% level
ns = non-significant

Appendix 4 Combination effect of balanced fertilizers and straw residue management on yield and yield components of blackgram during winter season, 2015 (Maubin Township)

Treatment	Seed yield (kg ha^{-1})	Pods per plant (no)	Seeds per pod (no)	100 seeds weight (g)
M_0F_0	444.78 h	5.68 e	5.83 c	5.02 c
M_0F_1	483.94 g	6.52 de	6.17 abc	5.38 bc
M_0F_2	507.56 g	8.01 cde	6.37 ab	5.38 bc
M_0F_3	547.70 f	7.85 cde	6.33 ab	5.65 ab
M_0F_4	597.23 e	8.88 cd	6.43 ab	5.68 ab
M_1F_0	612.31 e	7.35 cde	6.10 bc	5.58 ab
M_1F_1	640.06 d	9.38 bc	6.27 abc	5.58 ab
M_1F_2	671.07 c	11.32 ab	6.43 ab	5.71 ab
M_1F_3	720.75 b	12.08 a	6.57 a	5.58 ab
M_1F_4	758.48 a	12.12 a	6.60 a	5.88 a
$LSD_{0.05}$	27.61	2.40	0.44	0.37
Pr > F	ns	ns	ns	ns
CV (%)	13.14	15.66	4.08	3.87

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level
* = significant at 5% level
ns = non-significant

Appendix 5 Combination effect of balanced fertilizers and straw residue management on yield and yield components of blackgram during winter season, 2015 (Daik U Township)

Treatment	Seed yield (kg ha^{-1})	Pods per plant (no.)	Seeds per pod (no.)	100 seeds weight (g)
M_0F_0	526.30 b	7.23 c	6.27 ab	5.33 b
M_0F_1	603.50 b	7.73 c	6.10 b	5.80 a
M_0F_2	685.30 b	8.63 c	6.37 ab	5.77 a
M_0F_3	652.50 b	9.27 c	6.60 ab	5.77 a
M_0F_4	748.10 b	9.77 bc	6.37 ab	5.77 a
M_1F_0	602.10 b	8.00 c	6.53 ab	5.77 a
M_1F_1	723.70 b	10.00 bc	6.13 ab	5.67 ab
M_1F_2	1050.50 a	13.70 a	6.53 ab	5.85 a
M_1F_3	1273.90 a	13.27 a	6.70 a	6.00 a
M_1F_4	1088.30 a	12.33 ab	6.60 ab	5.90 a
$LSD_{0.05}$	292.41	2.97	0.57	0.36
Pr > F	ns	ns	ns	ns
CV (%)	21.43	17.3	5.22	3.64

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level
* = significant at 5% level
ns =non-significant

Appendix 6 Combination effect of balanced fertilizers and straw residue management on water use and water use efficiency of black gram during winter season, 2015 (Maubin Township)

Treatment	Water Use (mm)	Water Use Efficiency (kg ha^{-1} mm^{-1})
M_0F_0	153.35 a	2.90 i
M_0F_1	152.39 a	3.18 h
M_0F_2	150.96 ab	3.36 g
M_0F_3	153.81 a	3.56 f
M_0F_4	154.52 a	3.86 e
M_1F_0	151.25 ab	4.05 d
M_1F_1	152.99 a	4.18 d
M_1F_2	147.86 b	4.54 c
M_1F_3	148.55 b	4.85 b
M_1F_4	151.02 ab	5.02 a
$LSD_{0.05}$	3.68	0.17
Pr > F	ns	ns
CV (%)	1.42	10.53

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level
* = significant at 5% level
ns = non-significant

Appendix 7 Combination effect of balanced fertilizers and straw residue management on water use and water use efficiency of black gram during winter season, 2015 (Daik U Township)

Treatment	Water Use (mm)	Water Use Efficiency ($kg\ ha^{-1}\ mm^{-1}$)
M_0F_0	152.11 ab	3.46 c
M_0F_1	152.30 ab	3.96 c
M_0F_2	154.66 a	4.44 c
M_0F_3	149.12 b	4.38 c
M_0F_4	149.23 b	5.02 bc
M_1F_0	152.87 ab	3.94 c
M_1F_1	153.41 ab	4.73 bc
M_1F_2	153.57 ab	6.84 ab
M_1F_3	149.57 b	8.66 a
M_1F_4	150.64 ab	7.23 a
$LSD_{0.05}$	5.02	2.20
Pr > F	ns	ns
CV (%)	1.93	24.35

Means followed by the same letter in each column are not significantly different at 5% LSD

** = significant at 1% level

* = significant at 5% level

ns = non-significant