INFLUENCE OF UREA FORMS AND BIOCHAR LEVELS ON YIELD AND PROCESSING QUALITY OF POTATO

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INFLUENCE OF UREA FORMS AND BIOCHAR LEVELS ON THE YIELD AND PROCESSING QUALITY OF POTATO

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CERTIFICATE

*This is to certify that thesis entitled, "***INFLUENCE OF UREA FORMS AND BIOCHAR LEVELS ON YIELD AND PROCESSING QUALITY OF POTATO"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) in AGRONOMY****, embodies the result of a piece of bona-fide research work carried out by* ***NAIEM IMTIAZ****, Registration no.* **18-09147** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated:December, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Tuhin Suvra Roy
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Dedicated

To

My Beloved Parents

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ABSTRACT

The experiment conducted at Sher-e-Bangla Agricultural University's farm, Dhaka to study the influence of urea forms and biochar levels on yield and processing quality of potato during November 2019 to March 2020. The experiment consisted of two factors *viz.*, Factor A: Urea forms (2): 1. Prilled Urea (Up: 350 kg ha^{-1}), 2. Urea Super Granule (U_S: 350 kg ha^{-1}), and Factor B: Biochar levels (6): 1. B_0- Control, 2. B_1- 2 t ha^{-1}, 3. B_2- 4 t ha^{-1}, 4. B_3- 6 t ha^{-1}, 5. B_4-8 t ha^{-1}, and 6. B_5- 10 t ha^{-1}. The experiment was laid out in a Split Plot Design with three replications. Data were recorded on different growth, yield and quality attributes of potato. Results revealed that, urea forms and biochar levels had significant influence on most of the growth, yield and quality parameters of potato. In case of urea forms, maximum period for maturity (required 104 days), number of tuber hill^{-1} (8.79), average tuber weight (38.74 g), tuber yield (34.08 t ha^{-1}), yield of marketable potato (32.37 t ha^{-1}), firmness of tuber (37.46 N), dry matter content of tuber (20.167 %) and total antioxidant (454.56 Trolox µM 100 g^{-1} FW) were observed in Urea Super Granule (U_S) treatment. In respect of biochar levels, maximum period for maturity (required 100.33 days), number of tuber hill^{-1} (9.22), average tuber weight (41.69 g), tuber yield (35.48 t ha^{-1}), yield of marketable potato (34.01 t ha^{-1}) were observed in B_5 treatment which was statistically similar with B_4 treatment. The dry matter content of tuber (21.30 %), polyphenol (83.32 mg GA 100 g^{-1} FW) of potato, starch (15.3 %) and total antioxidant (502.01 Trolox µM 100 g^{-1} FW) were found maximum in B_4 treatment. Regarding combined effect, the maximum period for maturity (106.67 days), number of tuber hill^{-1} (9.54), average tuber weight (44.96 g), tuber yield (37.98 t ha^{-1}), yield of marketable potato (36.5 t ha^{-1}) were observed from U_SB_5 combination which was statistically similar with U_SB_4. The maximum dry matter content of tuber (21.80 %), polyphenol (GA mg 100 g^{-1} FW) of potato (87.52), starch of potato (15.9 %) and total antioxidant of potato (509.23 Trolox µM 100 g^{-1} FW) were exhibited from U_SB_4 combination. Although, the application of Urea Super Granule (U_S) along with 8 t ha^{-1} of biochar (B_4) application showed the best performance irrespective of yield and quality parameters but the application of Urea Super Granule (U_S) and 4 t ha^{-1} biochar (B_2) also satisfied the International processing standard *i.e.*, >20% dry matter, > 1.05 g cc^{-1} specific gravity and minimum reducing sugar (<0.3 mg g^{-1} FW). So, Bangladeshi potato farmers may apply Urea Super Granule (350 kg ha^{-1}) and 4 t ha^{-1} of biochar along with recommended dose of other inorganic fertilizers for producing processing quality potato without sacrificing yield.

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LIST OF ACRONYMS & ABBREBBIATION

AEZ	= Agro- Ecological Zone
AIS	= Agricultural Information System
BARC	= Bangladesh Agricultural Research Council
BBS	= Bangladesh Bureau of Statistics
BINA	= Bangladesh Institute of Nuclear Agriculture
BARI	= Bangladesh Agricultural Research Institute
cm	= Centimeter
cv.	= Cultivar
CGR	= Crop growth rate
CAR	= Conventional application rate
CV %	= Percentage of Coefficient of variance
DAT	= Days after transplanting
° C	= Degree Centigrade
DF	= Degree of Freedom
DAP	= Di-Ammonium Phosphate
DMA	= Dry Matter Accumulation
DMRT	= Duncan's Multiple Range Test
EC	= Emulsifiable Concentrate
et al.	= and others
etc.	= Etcetera
FAO	= Food and Agriculture Organization
FYM	= Farmyard Manure
g	= Gram
GDP	= Gross Domestic Product
HI	= Harvest Index
HYV	= High Yielding Variety
hr	= hour
K	= Potassium
Kg	= Kilogram
Kg ha^{-1}	= Kilogram per hectare
LV	= Local Variety
m	= Meter
m^2	= Meter squares
MV	= Modem Variety

MoP	= Muriate of Potash
mm	= Millimeter
N	= Nitrogen
NFAA	= Nitrogen Fertilizer Application Amount
NS	= Non Significant
P	= Phosphorus
ppm	= Parts per million
PU	= Prilled urea
SAU	= Sher-e- Bangla Agricultural University
S	= Sulphur
SRDI	= Soil Resources and Development Institute
t ha^{-1}	= Tons per hectare
TSP	= Triple Super Phosphate
TDM	= Total Dry Matter
TCRC	= Tuber Crop Research Centre
USG	= Urea Super Granules
UDP	= Urea Deep Placement
viz.	= Namely
Zn	= Zinc
%	= Per cent

CHAPTER I

INTRODUCTION

Potato (*Solanum tuberosum* L.) prominently known as alu 'The king of vegetable', is a tuber crop belongs to the family Solanaceae. It originated in the central Andean area of South America (Keeps, 1979). It is the 4th world crop after wheat, rice and maize. Bangladesh is the 8th potato producing country in the world. In Bangladesh, it ranks 2nd after rice in production (FAOSTAT, 2016). It is a staple diet in European countries and its utilization both in processed and fresh food form is increasing considerably in Asian countries (Brown, 2008). It is cultivated in nearly 150 countries and is the world's single most vital tuberous crop with an important role in the global food network and food security (Sing, 2010).

The yield of potato in Bangladesh is very low in comparison to that of the other leading potato growing countries of the world, 49.02 t ha^{-1} in USA, 48.99 t ha^{-1} in New Zealand, 42.48 t ha^{-1} in Denmark and 41.99 t ha^{-1} in Netherlands (FAOSTAT, 2016). The reasons responsible for such a low yield of potato in Bangladesh are use of imbalanced fertilizer, low organic matter content in soil, improper management of soil, and inadequate use of manure and organic matter etc. Further, use of imbalanced dose of chemical fertilizer by farmers has also deteriorated soil health and soil organic carbon which is a threat to soil sustainability (Sujatha *et al.*, 2014).

Agricultural land in our country has been degraded due to continuous pressure of modern agriculture resulting in decreased soil fertility. Severe degraded land has become the main causes of low crop productivity. Agricultural land that has been intensively cultivated for continuous cultivation of food crops causes severe degradation and further decreases yields (Sitorus *et al.*, 2011). Soils obtaining inorganic fertilizers continuously show a decrease in productivity and tend to suffer secondary nutrient deficiencies as well as micronutrients (Sheth *et al.*, 2017). So it is high time concern about soil health for ensuring sustainable crop production. The increasing population has resulted in increased land intensification and continuous production of potato with reduced fallow periods resulting in soil-fertility decline because of nutrient depletion (Walter *et al.*, 2011). The addition of soil amendment is necessary to restore the fertility of the soil. Biochar is one of the soil amendments that can improve soil fertility (Ding *et al.*, 2016 and Hunt *et al.*, 2010). Biochar is a black carbon manufactured through pyrolysis of biomass (Lehmann *et al.,* 2006), the high carbon materials produced from the slow pyrolysis (heating in the absence of oxygen) of biomass (Chan *et al.,* 2007[a]); and a fine-grained and porous substance, similar in its appearance to charcoal produced by natural burning or by the combustion of biomass under oxygen-limited conditions (Sohi *et al.,* 2009). It can be produced from a wide range of biomass sources, for example, woods and barks, agricultural wastes such as olive husks, corncobs and tea waste (Demirbas, 2004; Ioannidou and Zabaniotou, 2007), greenwaste (Chan *et al.,* 2007[b]), animal manures and other waste products (Downie *et al.,* 2007; Chan *et al.,* 2008; Lima *et al.,* 2008). As a pyrolysed product, biochar is protected from rapid microbial degradation and is able to securely sequester carbon, contributing to mitigation of greenhouse gas emissions (Lehmann *et al.,* 2006).

Nitrogen is of vital importance for plant growth due to being a part of amino acid, protein and chlorophyll molecule. Potato needs large amount of nitrogen. Different types of nutrient are essential for growth and development of potato. N is beneficial for its growth, development and protein synthesis. Nitrate content in tubers can be affected by several factors with the chemical form of nitrogen and time of harvest being especially important. Nitrate (NO_3) and ammonium (NH_4) are the forms of inorganic nitrogen commonly available for plant growth in soil.

Urea Super Granule (USG) technology is cost effective and environment friendly. Ministry of Agriculture (MoA) with technical assistance from the International Fertilizer Development Center (IFDC) has been implementing the Guti Urea Technology Extension Project in the country since November 2007. Deep placement of USG effectively increases N use efficiency (31.7%) compared to conventionally applied prilled urea (Jaiswal and Singh, 2001). broadcast application of urea on the surface soil causes losses up to 50% but point placement of USG in 10 cm depth may negligible loss. Urea Super Granule (USG) is a fertilizer that can be applied in the root zone at 8-10 cm depth of soil (reduced zone of rice soil) which can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the yield.

Nitrogen fertilization, irrigation, and cultivars also affect tuber characteristics such as tuber size, specific gravity and N concentration (Gregory and Sinmlonds, 1992;

Harris, 1992; Storey and Davies, 1992). Nitrogen is the most deficit nutrient element in Bangladesh soil. In general, farmers traditionally apply at least nitrogenous fertilizer to their crops for better yield. Potato production is being popularized day by day throughout the country. Currently Urea constitutes more than 70% of the fertilizers being consumed in Bangladesh. It is said that urea super granule (USG) is more efficient than that of prilled urea. USG minimizes N leaching and volatilization loss to a greater extent. Where large amount of urea fertilizer application are made, especially if they are not well incorporated, substantial losses (20 to 40%) of added N might be accepted. Application of USG in flooded rice improve efficiency more than 60% with an increase of about 15-20% rice yield over conventional urea application (Haque, 1998). Now, USG has been considered as a proven technology in rice production (Kumar *et al.,* 1989; Savant and Stangel, 1990).

During the last couple of years, farmer's are applying USG more efficiently in upland vegetable and fruit crops like brinjal, cabbage, cauliflower, tomato, potato, and on quick growing fruits like papaya, banana etc. (Anon, 2006-07). USG requirement is less than prilled urea in cabbage, cauliflower, brinjal and tomato. USG also increases yield of these crops. However, there is no recommendation of USG for potato crops and research findings in this regard are very scanty.

Nitrogen nutrition plays a predominant role for the quality of potato tubers (Mondy *et al.*, 1988). Decreasing specific gravity as a consequence of decreasing starch content (O'Beirne and Cassidy, 1990) is accompanied by increasing crude protein content. (Leszczynski and Lisinska, 1988) It is an essential plant nutrient element and is the most limiting due to its high mobility and different types of losses like leaching, volatilization and mobilization (Zaman *et al.,* 1993; Bhuiyan *et al.,* 1990). Eusof *et al.,* (1993) observed USG as an alternative source of nitrogen than prilled urea in terms of efficiency in wet land rice. Nitrogen requirement of potato and rate of urea is very high. Farmer's of Bangladesh grown potato in different regions through prilled urea with other fertilizers. The efficiency of the prilled urea is very low (Chowdhury and Khanif, 2001). Several research results showed the USG is more efficient than that of prilled urea. When prilled urea applied in the soil by broadcast method causes loss up to 50%, while the point placement method of USG in 8-10 cm depth showed negligible loss (De Dalta and Crasswell, 1982). So, during last 2-3 years, farmers are applying USG in upland vegetables and fruit due to it's minimizes of N fertilizer can increased through deep placement in the form of USG (Sanvant *et al.*, 1991).

Biochar represents as a stable form of carbon thus provides a good carbon storage strategy as a soil amendment (Galinato *et al.*, 2011). Previous studies showed that, it has good effect on some soil physical properties such as reducing soil bulk density (Mukherjee and Lal, 2013, Bussher *et al.*, 2011and Mankasingh *et al.*, 2011), increases the water retention capacity (Karhu *et al.*, 2011 and Vaccari *et al.*, 2011) and increases soil pH, EC, CEC of acidity soil (Abewa *et al.*, 2014) and reduced fertilizers need. Other it's impacts such as soil's aggregation or porosity greatly depend on soil type, biochar's rates and types (Busscher *et al.*, 2011 and Busscher *et al.*, 2010). The biochar treatments were found to increase the final vegetative biomass, root biomass, plant height and leaf number of lettuce and cabbage in all the cropping cycles compared to no biochar treatments (Carter *et al.*, 2013). Dou *et al.* (2012) revealed that biochar treatment could increase yield, sugar content and appearance quality of sweet potato, which was conducive to bringing more economic profits for farmers, and improving food safety through using organic fertilizers, and finally promoting sustainable crop production.

Potato is undoubtedly one of the most important crops which require both organic and mineral fertilizer for higher yield. Continuous use of inorganic fertilizer in crop cultivation is causing health hazards and creating problems to the environment including the pollution of air, water and soil. The use of chemical fertilizer is badly affecting the texture and structure of the soil, decreasing soil organic matter and hampering soil microorganism activity (Brady, 1990). The organic matter of most of the soils of Bangladesh is below 2% as compared to an ideal minimum value 4% (Bhuiyan, 1994). Biochar application increased vegetable yields by 4.7- 25.5% as compared to farmers' practices (Vinh *et al.*, 2014). Biochar application changes different soil physical properties, aggregate structure, increase soil C: N ratio. Biochar reduces soil bulk density, increase soil porosity, cation exchange capacity, soil pH, nutrient availability, increase C content and trap CO_2 gas within soil. Biochar mitigate climate change through slower return of terrestrial organic C as CO_2 gas to the atmosphere. Biochar reduces leaching loss which is main problem for N fertilizer by retain water into soil. Positive effects of biochar on N uptake have been reported mostly under greenhouse conditions or subtropical conditions (Chan *et al.*, 2008; Van *et al.*, 2009; Zhang *et al.*, 2012). Biochar have been found to be efficient in reclaiming heavy metal-polluted soils (Nigussie *et al.*, 2012), improved N-use efficiency in field crops (Chan *et al.*, 2008), and enhanced bio-logical N_2 fixation and beneficial mycorrhizal relationships in common beans (Rondon *et al.*, 2007). Day *et al.* (2004) emphasized that using biochar to sequester carbon in soil to mitigate climate change would only be economical if the sequestered C has beneficial soil amendment and/or fertilizer values. Some authors have reported that it can improve the quality of agricultural soils (Lehmann *et al.* 2003).

Considering the above facts the present work was conducted to evaluate the effect of urea forms and biochar levels on yield and quality of potato production with the following objectives:-

i. To find out the suitable forms of urea fertilizer for optimum yield and quality production of potato
ii. To find out the suitable level for biochar application in the field for optimum yield and quality production of potato
iii. To study the combined effect of urea forms and biochar levels on growth, yield and quality of potato production

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding the effect of urea forms and biochar levels on growth, yield and quality of potato to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of urea forms

2.1.1 Effect of urea forms on plant height

Azam *et al.* (2012) conducted a field experiment at the multi location testing (MLT) site, On Farm Research Division, BARI, Jhikargacha, Jessore under High Ganges River Floodplain (AEZ-11) during rabi seasons 2008-09 and 2009-10 to investigate the effect of urea super granule (USG) on the growth and yield of potato. The experiment was laid out in RCB design with six dispersed replications with the unit plot size 5m x 4m. Five treatments were the same in two rabi seasons. *viz.* T_1 = Recommended dose of nitrogen as prilled urea (PU), T_2 = Recommended dose of nitrogen as urea super granule (USG), T_3 = 10% less of recommended dose of nitrogen as USG, T_4 = 20% less of recommended dose of nitrogen as USG and T_5 = Farmers practice (average of 20 farmers N dose used as PU) Significant variation was observed in different treatments. The results showed that plant height, plant population m^{-2}, tuber $hill^{-1}$, tuber weight $hill^{-1}$ and tuber yield of potato were significantly affected by the treatments. In both years, the highest plant height (67.20 cm and 71.21 cm) was recorded from T_2 but T_2 and T_3 were significantly identical in 2008-09 and significantly difference in 2009-10.

Zohra (2012) conducted an experiment with 3 different potato varieties and highest plant height was recorded when 3 pellets of USG applied 4 adjacent hills.

Razib (2010) showed the highest plant height (55 cm) of potato when 120 kg N ha^{-1} was applied.

Mizan (2010) revealed that the highest plant height (60cm) was obtained from potato 140 kg N ha^{-1} and 120 kg N ha^{-1}.

Ahammed (2008) stated that leaf area increased with increasing level of nitrogen application from 40 kg N ha^{-1} up to 120 kg N ha^{-1}.

Salem (2006) noted that the nitrogen levels had a positive and significant effect on growth parameters of potato plants in robi season. Increasing nitrogen levels up to 70 kg ha^{-1} significantly increased leaf area index and plant height. The highest plant height at harvest was recorded about 56 cm when potato plants were fertilized with the highest nitrogen level of 120 kg ha^{-1}. On the contrary, the lowest value of the height was recorded about 40 cm when potato plants received no nitrogen fertilizer.

Meena *et al.* (2003) revealed that between two levels of N 100 and 200 kg ha^{-1}, application of 200 kg ha^{-1} significantly increased the plant height (53 cm) of potato and total number of tuber $hill^{-1}$ (73).

Ahmed *et al.* (2002) asserted that among 5 levels, 80 kg N ha^{-1} gave the highest plant height 48 cm and the height decreased gradually with decreased levels of nitrogen fertilizer application. Plants receiving no nitrogenous fertilizers were significantly shorter than other treatments. They also stated that nitrogen influences cell division and cell enlargement and ultimately increases plant height.

Alam (2002) suggested that plant height increased significantly with the increase of level of USG 4 $hills^{-1}$.

Mishra *et al.* (2000) resolved that the application of 76 kg N ha^{-1} USG at 14 DAT increased plant height, length, N uptake and consequently the tuber yields of potato.

Sahrawat *et al.* (1999) said that nitrogen level significantly influenced plant height of potato. Increasing levels of nitrogen increased the plant height significantly up to 120 kg N ha^{-1}.

Chowdhury *et al.* (1998) described that the longest plant height of 52 cm was produced by nitrogen application at 100 kg ha^{-1} and was followed by 75 kg ha^{-1} due to the excellent vegetative growth of potato.

Thakur (1992) showed that the highest plant height of potato was obtained from 120 kg N ha^{-1} and the lowest one from the control.

Rekhi *et al.* (1989) set an experiment on a loamy sand soil with potato cv. PR 106 providing 0, 37.5, 75.0 or 112.5 kg N ha^{-1} as prilled urea (PU) or USG. PU was applied in three equal splits at planting, tuber formation and USG was placed 8-10 cm deep in alternate rows, equidistant from 4 hills. They concluded that PU produced the longest plant, higher number of tuber and higher amount of nitrogen uptake.

Singh and Singh (1986) asserted that the plant height increased significantly with the increase in the levels of nitrogen from 27 to 87 kg N ha^{-1}. Deep placement of USG resulted in the highest plant height than pilled urea.

Wiersema, (1984) observed that effect of depth of placement of USG significantly influenced all growth characters and the yield attributes except plant height.

2.1.2 Effect of urea forms on plant vigor

Shahidullah *et al.* (2009) conducted an field experiment was at two locations; Shibganj and Sadar Upazilla during rabi season of 2007-08 to investigate the effect of Urea Super Granule (USG) on potato production. Five treatments were the same in two locations, *viz.* T_1=Control (N=Zero), T_2= 150 kg N ha^{-1} as prilled Urea, T_3= 20% less N (120kg N ha^{-1}) as USG, T_4= 10% less N (135 kg N ha^{-1}) as USG and T_5= 150 kg N ha^{-1} as USG. Increasing the application of N-as USG increased the plant vigor, tuber weight $hill^{-1}$ and yield significantly compared to control and same rate of N-as prilled Urea. Similar trend was found at Shibganj site. The highest plant vigor was found from T_5 treatment (8.0) followed by T_4 (7.0), T_2 (6.33), T_3 (5.67) and T_1 (3.0) treatment, respectively.

Tanaka *et al.* (1998) showed that at a higher N level, potato plants have vigorous growth, high maximum tuber per plant but lower percentage of effective tuber $hill^{-1}$.

2.1.3 Effect of urea forms on number of stem $hill^{-1}$

Zohra *et al.* (2012) noted that the number of stem $hill^{-1}$ was varied significantly due to different level of USG.

Ravichandran and Sing (2003) described that there was no appreciable change in stem $hill^{-1}$ due to higher dose of N above 150 kg ha^{-1}. They also showed an appreciable reduction in stem per $hill^{-1}$ at 250 kg N ha^{-1}.

Verma (2003) concluded the effects of deep placement of USG or PU on yields of cv. Verma reported that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govind by 25 and 22 t ha^{-1} respectively over yields with broadcast application of PU.

Singh and Kumar (1998) reported that tuber yield increased consistently with increasing N application up to 87 kg ha^{-1} USG produced the higher tuber yield of than ordinary urea applied in three equal split dressings and other N sources.

2.1.4 Effect of urea forms on number of tuber $hill^{-1}$

Azam *et al.* (2012) conducted a field experiment at the multi location testing (MLT) site, On Farm Research Division, BARI, Jhikargacha, Jessore under High Ganges River Floodplain (AEZ-11) during rabi seasons 2008-09 and 2009-10 to investigate the effect of urea super granule (USG) on the growth and yield of potato. The experiment was laid out in RCB design with six dispersed replications with the unit plot size 5m x 4m. Five treatments were the same in two rabi seasons. *viz.* T_1 = Recommended dose of nitrogen as prilled urea (PU), T_2 = Recommended dose of nitrogen as urea super granule (USG), T_3 = 10% less of recommended dose of nitrogen as USG, T_4 = 20% less of recommended dose of nitrogen as USG and T_5 = Farmers practice (average of 20 farmers N dose used as PU) Significant variation was observed in different treatments. The results showed that plant height, plant population m^{-2}, tuber $hill^{-1}$, tuber weight $hill^{-1}$ and tuber yield of potato were significantly affected by the treatments. The highest tuber per hill was observed from T_2 treatment, which was statistically similar with T_3 & T_4 treatments in 2008-09. The highest Tuber per hill was recorded from T_3 treatment followed by T_2 treatment but there was no significance difference among the T_1, T_4 and T_5 treatments in 2009-10.

Azam (2009) conducted an experiment with 3 varieties and observed, in general, the number of total tuber $hill^{-1}$ was increased as the USG level increased but highest no. of total tuber $hill^{-1}$ was produced when 120 kg N ha^{-1}applied as USG.

Hasan (2007) conducted an experiment during the rabi season of 2006 and recorded the increased number of tuber $hill^{-1}$ with increased nitrogen level used USG.

Shahidullah *et al.* (2009) conducted an field experiment was at two locations; Shibganj and Sadar Upazilla during rabi season of 2007-08 to investigate the effect of Urea Super Granule (USG) on potato production. Five treatments were the same in two locations, *viz.* T_1=Control (N=Zero), T_2= 150 kg N ha^{-1} as prilled Urea, T_3= 20% less N (120kg N ha^{-1}) as USG, T_4= 10% less N (135 kg N ha^{-1}) as USG and T_5= 150 kg N ha^{-1} as USG. Result showed that Tuber weight per hill was increased due to application of USG. Tuber weight per hill was ranged from 190-385 gm $hill^{-1}$. The highest tuber weight was obtained from T_5 treatment (385 gm) at Shibganj site and the lowest was found T_1 treatment (190 gm) from Bogra sadar site.

Singh and Shivay (2003) reported that the effective tuber $hill^{-1}$ was significantly affected by the level of nitrogen and increasing levels of nitrogen significantly increased the number of effective tuber $hill^{-1}$.

Alam (2002) showed that total tuber $hill^{-1}$ and effective tuber $hill^{-1}$ increased significantly with the increase of level of USG, when USG was applied as one, two, three and four granules 4 $hills^{-1}$ during the rabi season.

Elia *et al.* (1998) stated that the yield attributes of potato like number of productive tuber m^{-2} and tuber weight increased with increasing levels of nitrogen.

Mirzeo and Reddy (1989) effort different modified urea materials and levels of N (30, 60 and 90 kg N ha^{-1}). They stated that root zone placement of USG produced the highest number of tuber at 30 or 60 days after planting.

Tuber of potato plant is strongly influenced by nitrogen supply (BINA, 1998; BARI, 2000) and adequate nitrogen is necessary during tubering stage to ensure sufficient number of mature tuber.

2.1.5 Effect of urea forms on weight of tuber (g)

Azam *et al.* (2012) conducted a field experiment at the multilocation testing (MLT) site, On Farm Research Division, BARI, Jhikargacha, Jessore under High Ganges River Floodplain (AEZ-11) during rabi seasons 2008-09 and 2009-10 to investigate the effect of urea super granule (USG) on the growth and yield of potato. The experiment was laid out in RCB design with six dispersed replications with the unit plot size 5m x 4m. Five treatments were the same in two rabi seasons. *viz.* T_1 =

Recommended dose of nitrogen as prilled urea (PU), T_2 = Recommended dose of nitrogen as urea super granule (USG), T_3 = 10% less of recommended dose of nitrogen as USG, T_4 = 20% less of recommended dose of nitrogen as USG and T_5 = Farmers practice (average of 20 farmers N dose used as PU). Significant variation was observed in different treatments. The results showed that plant height, plant population m^{-2}, tuber $hill^{-1}$, tuber weight $hill^{-1}$ and tuber yield of potato were significantly affected by the treatments. Higher tuber weight $hill^{-1}$ (335.01 and 325.25 gm) were found in treatment T_2, that were statistically identically with T_5 (325.25 and 314.34 gm) followed by T_3 (300.15 and 305.95 gm) for both the years, respectively.

Azam *et al.* (2009) set up an experiment during the rabi season with 3 different potato varieties by using both USG and prilled urea as a source of N. He reported that source and dose of nitrogen did not show significant effect on tuber weight. The highest tuber weight (50 g) was concluded with USG applied at 120 kg N ha^{-1} and the lowest (40 g) tuber weight was reported at 110 kg N ha^{-1} as PU.

Chopra and Chopra (2004) reported that N had significant effects on yield attributes such as plant height and tuber weight. Cumulative effect of yield attributing and nutrient characters stated that significant increase in tuber yield at 120 kg N ha^{-1}over 80 kg N ha^{-1} and the control.

Russell (1986) conducted an experiment with the treatments comprised of 4 N levels (0, 60, 120 and 180 kg N ha^{-1}) and results showed that N had significant effects on yield attributes such as plant height and tuber weight. Cumulative effects of yield attributing characters resulted in significant increase and tuber yield at 120 kg N ha^{-1} over 60 kg N ha^{-1}.

2.1.6 Effect of urea forms on yield of tuber (t ha^{-1})

Azam *et al.* (2012) conducted a field experiment at the multilocation testing (MLT) site, On Farm Research Division, BARI, Jhikargacha, Jessore under High Ganges River Floodplain (AEZ-11) during rabi seasons 2008-09 and 2009-10 to investigate the effect of urea super granule (USG) on the growth and yield of potato. The experiment was laid out in RCB design with six dispersed replications with the unit plot size 5m x 4m. Five treatments were the same in two rabi seasons. *viz.* T_1 =

Recommended dose of nitrogen as prilled urea (PU), T_2 = Recommended dose of nitrogen as urea super granule (USG), T_3 = 10% less of recommended dose of nitrogen as USG, T_4 = 20% less of recommended dose of nitrogen as USG and T_5 = Farmers practice (average of 20 farmers N dose used as PU) Significant variation was observed in different treatments. The highest yield of potato 33.21 t ha^{-1} were obtained from the recommended N dose of USG followed by USG 10% less than recommended dose of N (31.51 t ha^{-1}) during 2008-09. In the year 2009-10 higher yield was obtained from the T_2 treatment (32.33 t ha^{-1}) followed by T_3 (30.87 t ha^{-1}). By reducing 10% N losts through USG application more or equal returns can be obtained over prilled urea application.

Mishra *et al.* (1999) noted that apparent N recovery in potato also increased from 21% for PU to 40% for USG. Here potato showed a greater response to N upon USG placement than split application of PU.

Singh and Kumar (1998) reported that tuber yield increased consistently with increasing N application up to 87 kg ha^{-1} USG produced the higher tuber yield of than ordinary urea applied in three equal split dressings and other N sources. Verma (2003) concluded the effects of deep placement of USG or PU on yields of cv. Verma reported that with random transplanting, deep placement of USG increased yield of cv. Jaya and Govind by 25 and 22 t ha^{-1} respectively over yields with broadcast application of PU.

2.2 Effect of Biochar levels

2.2.1 Effect of biochar levels on plant height

Mollick *et al.* (2020) was conducted an experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The experiments consist of 9 treatments. The experiment consist of 9 treatments as T_1=Control (no chemical fertilizer and biochar), T_2=RFD (Recommended Fertilizer Dose); T_3=RFD + Biochar @ 2.5 ton ha^{-1}; T_4=RFD + Biochar @ 5.0 t ha^{-1}; T_5=RFD + Biochar @ 7.5 t ha^{-1}; T_6=1/2 of RFD + Biochar @ 2.5 t ha^{-1}; T_7=½ of RFD + Biochar @ 5.0 t ha^{-1}; T_8=½ of

RFD + Biochar @ 7.5 t ha^{-1};T_9=Biochar @ 10 t ha^{-1}. RFD (Recommended Fertilizer Dose): for potato N_{150}, P_{30}, K_{140}, S_{15}, Zn_3 kg ha^{-1} (FRG, 2012). The experiment was laid out in a Randomized Complete Block Design with three replications. The tested variety was BARI Alu-7 (Diamant). Data were collected on different yield attributes, growth and quality of potato and postharvest soil analysis. The results indicated that biochar application significantly ($p<0.05$) increased plant height. The maximum plant height 63.23 cm at harvesting which was recorded from T_5 treatment whereas, the minimum plant height was recorded from control treatment. Plant height was significantly ($p<0.05$) increased due to application of biochar.

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application rates (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} = 4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Concerning the effect of biochar application, data show that potato plants grown in sandy soil applied with biochar had a significant response in respect of plant height, number of main stems, leaves and tubers $plant^{-1}$ and leaf area $plant^{-1}$ in both studied seasons. Potato plants grown in sandy soil amended with different biochar application rates had better morphological traits compared to control (without biochar) in both seasons. Plant height, number of main stems, leaves and tubers $plant^{-1}$ and leaf area $plant^{-1}$ significantly increased with increasing biochar application rates up to 11 m^3 ha^{-1}

2.2.2 Effect of biochar levels on the number of stems $hill^{-1}$

Mollick *et al.* (2020) was conducted an experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The experiment consists of 9 treatments. The experiment consist of 9 treatments as T_1=Control (no chemical fertilizer and biochar), T_2=RFD (Recommended Fertilizer Dose); T_3=RFD + Biochar @ 2.5 ton ha^{-1}; T_4=RFD + Biochar @ 5.0 t ha^{-1}; T_5=RFD + Biochar @ 7.5 t ha^{-1}; T_6=1/2 of RFD + Biochar @ 2.5 t ha^{-1}; T_7=½ of RFD + Biochar @ 5.0 t ha^{-1}; T_8=½ of RFD + Biochar @ 7.5 t ha^{-1}; T_9=Biochar @ 10 t ha^{-1}. RFD (Recommended Fertilizer Dose): for potato N_{150}, P_{30}, K_{140}, S_{15}, Zn_3 kg ha^{-1} (FRG, 2012). The experiment was laid out in a Randomized Complete Block Design with three replications. The tested variety was BARI Alu-7 (Diamant). Data were collected on different yield attributes, growth and quality of potato and postharvest soil analysis. The number of stems hill^{1} at haulm cutting stage significantly (p<0.05) increased only over control. The maximum stem numbers hill^{-1} (5.17) was obtained from T_6 treatment which was statistically not significant (p<0.05) with other treatments.

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} = 4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Concerning the effect of biochar application, data show that potato plants grown in sandy soil applied with biochar had a significant response in respect of plant height, number of main stems, leaves and tubers plant^{-1} and leaf area plant^{-1} in both studied seasons. Potato plants grown in sandy soil amended with different biochar application rates had better morphological traits compared to control (without biochar) in both seasons. Plant height, number of main stems, leaves and tubers plant^{-1} and leaf area plant^{-1} significantly increased with increasing biochar application rates up to 11.9 m^3 ha^{-1}.

2.2.3 Effect of biochar levels on tuber yield of potato (t ha^{-1})

Mollick *et al.* (2020) was conducted an experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The experiment consists of 9 treatments. The experiment consist of 9 treatments as T_1=Control (no chemical fertilizer and biochar), T_2=RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2.5 ton ha^{-1}; T_4= RFD + Biochar @ 5.0 t ha^{-1}; T_5= RFD + Biochar @ 7.5 t ha^{-1}; T_6=1/2 of RFD + Biochar @ 2.5 t ha^{-1}; T_7=½ of RFD + Biochar @ 5.0 t ha^{-1}; T_8=½ of RFD + Biochar @ 7.5 t ha^{-1};T_9= Biochar @ 10 t ha^{-1}. RFD (Recommended Fertilizer Dose): for potato N_{150}, P_{30}, K_{140}, S_{15}, Zn_3 kg ha^{-1} (FRG, 2012). The experiment was laid out in a Randomized Complete Block Design with three replications. The tested variety was BARI Alu-7 (Diamant). Data were collected on different yield attributes, growth and quality of potato and postharvest soil analysis. The tuber yield of potato increased significantly (p<0.05) due to application of biochar in combination with chemical fertilizers. The highest tuber yield (35.76 t ha^{-1}) was obtained from T_5 (RFD + Biochar @ 7.5 t ha^{-1}) treatment lowest tuber yield (14.51 t ha^{-1}) was obtained from T_1 (control) treatment.

Upadhya *et al.* (2020) conducted and experiment to know the response of five types of biochar (*Lantana camara*, *Ipomoea carnea*, rice husk, sawdust, no biochar) on growth and yield attributes of potato was evaluated. The experiment was laid out in randomized complete block design with six replications in rainfed areas of two different environments (Jiri in 2018 and Pawati in 2019) of Nepal. The popular early maturing potato variety 'Desiree' was used in the experiment. The spacing was maintained 60 cm between rows and 25 cm between plants in the plot size of 7.2 m^2. Seed tubers were planted in the 1st week of February and harvested in the 4^{th} week of May. Recommended fertilizers (100:100:60 kg ha^{-1} NPK + 20 t ha^{-1} farmyard manure) and biochar at 2 t ha^{-1} were applied to the soil. Seed tubers were completely covered with an equal amount of biochar before covering with the soil. The results revealed that the total yield and marketable yield of potato varied with biochar types. The potato tuber yield was found higher and red ants' infestation was lower in plots applied with biochar as compared to control plots (without biochar). The use of biochar derived from *Lantana camera* produced the highest number of tubers (6.1 tubers $plant^{-1}$), the greatest weight of tubers (286.1 g $plant^{-1}$) and the least damage of red ants on tubers (4.7%) followed by sawdust (6.0 tubers $plant^{-1}$, 263.6 g tuber weight $plant^{-1}$ and 7.8% damaged tubers by red ants). The findings provide new information on the understanding of biochar effect on increased marketable yield of potato in rainfed lands by reducing damage from red ants.

Shahidullah *et al.* (2009) conducted an field experiment was at two locations; Shibganj and Sadar Upazilla during rabi season of 2007-08 to investigate the effect of Urea Super Granule (USG) on potato production. Five treatments were the same in two locations, *viz.* T_1=Control (N=Zero), T_2= 150 kg N ha^{-1} as prilled Urea, T_3= 20% less N (120kg N ha^{-1}) as USG, T_4= 10% less N (135 kg N ha^{-1}) as USG and T_5= 150 kg N ha^{-1} as USG. The highest yield was found in T_5 treatmnts at Shigganj (22.64 t ha^{-1}) and Bogra sadar (24.32 t ha^{-1}).

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} =

4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Result revealed that Number of tubers plant^{-1}, tuber yield plant^{-1}, yield of grade 2 and 3, marketable yield and total yield ha^{-1} were significantly increased with increasing biochar application rates up to 11.9 m^3 ha^{-1}.

Chan *et al.*, (2007[a]) conducted glasshouse pot trial experiments where the agronomic benefits of green waste biochar applied as a soil amendment were investigated. Radish was planted in an acidic hard setting soil with a low soil organic carbon content, and its dry matter production was later analyzed. The DM production of radish using green wastes and ammonium nitrate were investigated in the absence and presence of N fertilizer. It was found that in the absence of N fertilizer, biochar application did not at all cause an increase in the crop yield. However, increasing biochar application rates (10, 50 and 100 t ha^{-1}) resulted in significant yield increases in the presence of 100 kg ha^{-1} of N fertilizer.

2.2.4 Effect of biochar levels on dry matter content (g)

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application rates (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} = 4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Fertilizing potato plants with biochar at different application rates (2.97, 5.95 and 11.9 m^3 ha^{-1}) markedly increased dry weight/plant, compared to control. DW of roots, stems, leaves and up to 11.9 m^3 ha^{-1} in both tested seasons. The increases in total DW plant^{-1} were about 16.84 and 15.60% tubers, as well as total DW/plant significantly increased with increasing of biochar application rate for biochar applied at 2.97 m^3 ha^{-1} over the control in the first and second seasons, respectively. While, such increases were about, 32.90 and 28.93% for biochar applied at 5.95 m^3 ha^{-1} and were about 58.72 and 50.13% for biochar applied at 11.9 m^3 ha^{-1} over the control in the first and second season, respectively.

Walter And Rao (2015) suggested that the biomass of an invasive and obnoxious weed, kunai grass (*Imperata cylindrica*), is uncontrollably burnt in Papua New Guinea in subsistence farming systems resulting in unwarranted negative environmental consequences. Exploring the possibility of sustainable utilization of biochar produced from the weed biomass along with a standard feedstock-rice husk (*Oryza sativa*). Biochar were produced with lab-scale pyrolysis at 550^0 C, characterized for chemical properties and plant nutrient composition. Further, agronomic efficacy of soil incorporation of biochar (5 t ha^{-1}) or co-applied with mineral fertilizers (100, 11, and 62 kg ha^{-1} N, P, K, respectively) was tested for sweet potato (*Ipomoea batatas* L. Lam) in a field experiment. The two biochar differed significantly (P < 5%) with respect to recovery from the feedstock's, chemical characters and nutrient composition. Kunai grass biochar was poorer in nutrients (< 1%) with distinctly alkaline pH and higher electrical conductivity. Biochar amendment to soil showed significant (P < 5%) improvement of soil moisture, while co-application of biochar along with mineral fertilizers showed soil moisture decrease. Biochar amendment improved the growth parameters and total tuber yield of sweet potato by about 20%, while co-application with mineral fertilizers augmented total tuber yield by 100% and above-ground biomass yields by > 75%. Besides, improving agronomic performance of sweet potato crop, co-application of biochar with mineral fertilizers enhanced uptake of N, P, K, Ca, Mg, and S. Production and utilization of biochar in sweet-potato production could offer an efficient means of disposing biomass of kunai grass with concomitant productivity improvement in Papua New Guinea.

Numerous and regular applications of biochar to soil are not necessary because biochar is not warranted as a fertilizer (Lehmann and Joseph 2009). In a pot trial carried out by Chan *et al.*, (2007[a]) a significant increase in the dry matter (DM) production of radish resulted when N fertilizer was used together with biochar. The results showed that in the presence of N fertilizer, there was a 95 to 266 % variation in yield for soils with no biochar additions, in comparison to those with the highest rate of 100 t ha^{-1}. Improved fertilizer-use efficiency, referring to crops giving rise to higher yield per unit of fertilizer applied (Chan and Xu 2009), was thus shown as a major positive attribute of the application of biochar.

2.2.5 Effect of biochar levels on specific gravity of tuber

Mollick *et al.* (2020) was conducted an experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The experiment consists of 9 treatments. The experiment consist of 9 treatments as T_1=Control (no chemical fertilizer and biochar), T_2=RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2.5 t ha^{-1}; T_4= RFD + Biochar @ 5.0 t ha^{-1}; T_5= RFD + Biochar @ 7.5 t ha^{-1}; T_6=1/2 of RFD + Biochar @ 2.5 t ha^{-1}; T_7=½ of RFD + Biochar @ 5.0 t ha^{-1}; T_8=½ of RFD + Biochar @ 7.5 t ha^{-1};T_9= Biochar @ 10 t ha^{-1}. RFD (Recommended Fertilizer Dose): for potato N_{150}, P_{30}, K_{140}, S_{15}, Zn_3 kg ha^{-1} (FRG, 2012). The experiment was laid out in a Randomized Complete Block Design with three replications. The tested variety was BARI Alu-7 (Diamant). Data were collected on different yield attributes, growth and quality of potato and postharvest soil analysis. Specific gravity of tuber increased significantly (p<0.05) with different levels of biochar application. The highest specific gravity (1.12) of tuber was recorded from T_5 (RFD + Biochar @ 7.5 t ha^{-1}) treatment and the lowest was found from T_1 (1.03) treatment

2.2.6 Effect of biochar levels on category wise potato yield

Mollick *et al.* (2020) was conducted an experiment in Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during the period from November, 2017 to March, 2018 in rabi season to observe the effect of biochar on the yield and quality of potato tuber and to find out the optimum dose of biochar along with inorganic fertilizer for achieving the maximum yield of potato. The experiment consists of 9 treatments. The experiment consist of 9 treatments as T_1=Control (no chemical fertilizer and biochar), T_2= RFD (Recommended Fertilizer Dose); T_3= RFD + Biochar @ 2.5 t ha^{-1}; T_4= RFD + Biochar @ 5.0 t ha^{-1}; T_5= RFD + Biochar @ 7.5 t ha^{-1}; T_6=1/2 of RFD + Biochar @ 2.5 t ha^{-1}; T_7=½ of RFD + Biochar @ 5.0 t ha^{-1}; T_8=½ of RFD + Biochar @ 7.5 t ha^{-1};T_9= Biochar @ 10 t ha^{-1}. RFD (Recommended Fertilizer Dose): for potato N_{150}, P_{30}, K_{140}, S_{15}, Zn_3 kg ha^{-1} (FRG, 2012). The experiment was laid out in a Randomized Complete Block Design with three replications. The tested variety was BARI Alu-7 (Diamant). Data were collected on different yield attributes, growth and quality of potato and postharvest soil analysis. Based on weight, tubers have been graded into marketable tuber (>20 g) and non-marketable tuber (<20 g). The results indicate that there was significant difference in the treatments in respect of production of different grades of tubers. The highest percentage (31.86%) of non-marketable tuber (<20 g) was produced from control treatment and the lowest percentage (23.55%) of non-marketable tuber (<20 g) was produced from T_5 treatment. The maximum percentage (76.45%) of marketable tuber (>20 g) was produced from T_5 (RFD + Biochar @ 7.5 t ha^{-1}) treatment while the minimum percentage (68.14%) of marketable tuber was produced from T_1 treatment.

Upadhya *et al.* (2020) conducted and experiment to know the response of five types of biochar (*Lantana camara*, *Ipomoea carnea*, rice husk, sawdust, no biochar) on growth and yield attributes of potato was evaluated. The experiment was laid out in randomized complete block design with six replications in rainfed areas of two different environments (Jiri in 2018 and Pawati in 2019) of Nepal. The popular early maturing potato variety 'Desiree' was used in the experiment. The spacing was maintained 60 cm between rows and 25 cm between plants in the plot size of 7.2 m^2. Seed tubers were planted in the 1st week of February and harvested in the 4^{th} week of May. Recommended fertilizers (100:100:60 kg ha^{-1} NPK + 20 t ha^{-1} farmyard manure) and biochar at 2 t ha^{-1} were applied to the soil. Seed tubers were completely covered with an equal amount of biochar before covering with the soil. The results revealed that the total yield and marketable yield of potato varied with biochar types. The potato tuber yield was found higher and red ants infestation was lower in plots applied with biochar as compared to control plots (without biochar). The use of biochar derived from *Lantana camera* produced the highest number of tubers (6.1 tubers $plant^{-1}$), the greatest weight of tubers (286.1 g $plant^{-1}$) and the least damage of red ants on tubers (4.7%) followed by sawdust (6.0 tubers $plant^{-1}$, 263.6 g tuber weight $plant^{-1}$ and 7.8% damaged tubers by red ants). The findings provide new information on the understanding of biochar effect on increased marketable yield of potato in rainfed lands by reducing damage from red ants

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application rates (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} = 4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Result revealed that Number of tubers plant^{-1}, tuber yield plant^{-1}, yield of grade 2 and 3, marketable yield and total yield ha^{-1} were significantly increased with increasing biochar application rates up to 11.9 m^3 ha^{-1} in both seasons. The increases in total yield were about 12.27 and 14% for biochar application rate at 2.97 m^3 ha^{-1}, 21.04 and 22.26% for biochar rate at 5.95 m^3 ha^{-1} while it were 28.48 and 35.05% for biochar application rate at 11.9 m^3 ha^{-1} over the control (without biochar) in the first and second seasons, respectively. Treating potato plants with biochar at different rates had no significant effect on average tuber weight in both seasons. The simulative effect of biochar at 11.9 m^3 ha^{-1} on total yield ha^{-1} may be due to that biochar at 11.9 m^3 ha^{-1} increased the morphological traits, total dry weight, photosynthetic pigments and mineral contents, number of tubers plant^{-1}, tuber yield plant^{-1} and yield of grades 1 and 3.

2.2.7 Effect of biochar levels on chemical properties of potato

Youseef *et al.* (2017) was carried out a study during the two summer seasons of 2016 and 2017 to study the effect of biochar application rates (0, 2.97, 5.95 and 11.9 m^3 ha^{-1} = 4200 m^2) on productivity and tubers quality of three potato cultivars i.e., Accent, Cara and Spunta grown under sandy soil conditions. Data of the experiment showed that N, P, K, total protein, total carbohydrate, starch and dry matter contents (%) in tubers significantly increased with increasing biochar application rates up to 11.9 m^3 ha^{-1}, with no significant differences with 5.95 m^3 ha^{-1} with respect to N, total protein, total carbohydrate, starch and DM (%). Biochar at 5.95 m^3 ha^{-1} increased contents (%) of N, total protein, total carbohydrate, starch and DM, whereas biochar at 11.9 m^3 ha^{-1} increased P and K contents (%) in potato tubers.

CHAPTER III

MATERIALS AND METHODS

The study was carried to find out the effect of urea forms and biochar levels on yield and quality of potato. This chapter presents a brief description about experimental period, site description, soil and climatic condition of the experimental area, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of experiments and methods are described below-

3.1 Experimental site

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain. For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in (Appendix-I).

3.2 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year. The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The weather data during the study period at the experimental site including maximum and minimum temperature, total rainfall and relative humidity were shown in (Appendix-II).

3.3 Soil

The soil of experimental field was general soil type and shallow red brown terrace soils under Tejgaon series. The selected plot was higher than the flood level and sufficient sunshine was available having availability of irrigation and drainage system during the experimental period. The experimental plot was a high land. The top soil was characterized by silty clay in texture, olive- gray whitish with common fine to medium distinct dark whitish brown mottles was seen on the top soil and the soil had pH- 6.3 and organic carbon- 1.8%. The experimental area was flat and medium high topography with available easy irrigation and drainage system. The soil status was shown in (Appendix III).

3.4 Details of the experiment

3.4.1 Treatments

Two sets of treatments included in the experiment were as follows:

Factor A: Urea forms - 2

U_p= Prilled urea

U_s= Urea Super Granule

Factor B: Biochar levels - 6

B_0 = Control

B_1 = 2 t ha^{-1}

B_2 = 4 t ha^{-1}

B_3 = 6 t ha^{-1}

B_4 = 8 t ha^{-1}

B_5 = 10 t ha^{-1}

All the fertilizers were applied at their recommended doses and the rate of fertilizers have been presented in section 3.5.3.

3.4.2 Experimental design

The experiment was laid out in split-plot design where urea forms was assigned in the main plot and biochar levels in the subplot having 3 replications. There were 36 unit plots altogether in the experiment. The size of each unit plot was 2.6 m × 1.2 m. Row to row and plat to plant distances were 60 cm and 25 cm, respectively. Distance maintained between replication and plots were 1.0 m and 0.8 m. The final layout of the experimental plots has been shown in (Appendix-IV).

3.5 Crop management

3.5.1 Seed collection

Seeds of BARI alu- 29 (Courage) were collected from Bangladesh Agricultural Institute (BARI), Joydebpur, Gazipur.

3.5.2 Land preparation

The land of the experimental field was first opened on November 11, 2019 with a power tiller. Then it was exposed under the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better plant stand and yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The soil was treated with Furadan 5G @ 20 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm.

3.5.3 Fertilizers

The crop was fertilized as per recommendation of TCRC (2018). Urea, triple superphosphate (TSP), zinc oxide and boric acid were used as sources of nitrogen, phosphorus, potassium, gypsum, zinc, boron and cowdung respectively. The doses of fertilizers were 350, 220, 250, 120, 10, 8 and 10000 kg ha^{-1} for urea, TSP, MP, Gypsum, $ZnSO_4$, boric acid and cowdung respectively. Cowdung was applied 10 days before final land preparation. Total amount of TSP, ZnO, boric acid and half of urea was applied at basal doses during final land preparation. The remaining 50% prilled urea was side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up and the urea super granule was applied per plant in two split. Once during the land preparation and another split were applied at 45 DAP. Different dose of biochar were applied as per treatment advised.

3.5.4 Seed treatment

Seeds were treated with Provex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease.

3.5.5 Seed sowing

Healthy and uniform sized potato tuber seeds were collected. Seed of potato were sown in lines each having a line to line distance of 60 cm and plant to plant distance of 25 cm having 1 tuber hole^{-1} under direct sowing in the well-prepared plots at a depth of 3-4 cm on November 24, 2019 for easy emergence.

3.6 Intercultural operations

3.6.1 Earthing up

Earthing up was done twice during growing period. The first earthing up was done at 25 DAP on 19 December, 2019 and second earthing up was done after 15 days of first earthing up on 3 January, 2020.

3.6.2 Removal of weeds

It was required to keep the crop free from weeds and to keep the soil loose for proper aeration and for proper growth and development of maize plant. First weeding was done two weeks after emergence. Another weeding was done before 2nd top dressing of urea.

3.6.3 Thinning and gap filling

Tubers were emerged at 6th and 7th days after sowing. After emergence of seedling, gap filling was completed within 15 days after sowing. Overcrowded seedlings were thinned out for two times. First thinning was done after 10 days of sowing which was done to remove unhealthy and lineless seedlings. The second thinning was done 15 days after first thinning keeping one healthy seedling in each hill according to the treatment.

3.6.4 Irrigation and drainage

Three irrigations were provided throughout the growing period in controlled way. The first irrigation was given at 25 DAP. Subsequently, another two irrigations were given at 45 and 60 DAP. Flood irrigation was provided on urea super granule plot and others plot were localized irrigation provided.

3.6.5 Control of insects and diseases

Furadan 5G @ 10 kg ha^{-1} was applied in soil at the time of final land reparation on 10 November, 2010 to control cut worm. Dithane M-45 was sprayed in 2 installments at an interval of 15 days from 50 DAP as preventive measure against late blight disease.

3.6.6 Haulm cutting

Haulm cutting was done at February 18, 2020 at 85 DAP, when 40-50% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening. The cut haulm was collected, bagged and tagged separately for further data collection**.**

3.7 Harvest and post-harvest operation

Harvesting of potato was done on February 25, 2020 at 7 days after haulm cutting. The potatoes of each plot were separately harvested, bagged and tagged and brought to the laboratory. The yield of potato $plot^{-1}$ was determined in gram. Harvesting was done manually by hand.

3.8 Collection of data

The following parameters were recorded and their mean values were calculated from the sample plants.

A. Crop growth characters

- Days to 50% emergence
- Plant vigor (1-10) at 55 DAP
- Leaf number at different DAP
- Plant height at different DAP (cm)
- Number of stem $hill^{-1}$ at 80 DAP

- Days to crop maturity

B. Yield and yield components

- No of tuber hill^{-1}
- Average tuber weight (g)
- Tuber yield (t ha^{-1})
- Yield of marketable potato (>20 g)
- Category wise potato yield (t ha^{-1})

C. Quality characters

- Specific gravity
- Total soluble solid (^{o} Brix) (TSS)
- Firmness (N)
- Dry matter content of tuber (g)
- Skin color and flesh color of tuber
- Polyphenol (GA mg 100 g^{-1} FW)
- Starch (%)
- Non-Reducing Sugar (mg g^{-1}FW)
- Reducing Sugar (mg g^{-1}FW)
- Antioxident (Trolox µ Mol 100 g^{-1} FW)

Days to 50% emergence

Time required to emergence half of the total population of a plot are recorded.

Plant vigor

Plant vigor is the measure of the increase of plant growth or foliage volume through time after planting. At 55 days after planting (DAP) the plant vigor is measured through eye estimation on a scale of 1-10.

Plant height (cm)

Plant height refers to the length of the plant from ground level to the tip of the tallest stem. It was measured at 30, 55 and 80 days after planting (DAP). The height of selected plant was measured in cm with the help of a meter scale and mean was calculated.

Number of stems hill^{-1}

Number of stems hill^{-1} was counted at the time of haulm cutting. Stem numbers hill^{-1} was recorded by counting all stem from each plot.

Leaves plant^{-1}:

The number of leaves was counted from five plants of each plot periodically after every 25 days starting from 30 DAP to 80 DAP and mean value was calculated.

Days to crop maturity:

It is the time needed for the plant to reach maturity. The time (days) between the days of planting to the days of harvesting are recorded as days to crop maturity.

No. of tuber hill^{-1}:

Number of tubers hill^{-1} was counted at harvest. Tuber numbers hill^{-1} was recorded by counting all tubers from sample plant.

Average weight of tuber (g):

Average weight of tuber was measured by using the following formula

$$\text{Average weight of tuber} = \frac{\text{Yield of tuber/plot}}{\text{Number of tuber/plot}}$$

Yield of tuber (t ha^{-1}):

Tubers of each plot were collected separately from which yield of tuber hill- was recorded in kilogram and converted to ton per hectare.

$$\text{Tuber yield} = \frac{\text{Tuber yield per plot (kg) x 10000}}{\text{Area of plot (sq m)} \times 1000}$$

Yield of marketable potato (>20 g):

On the basis of weight, the tubers have been graded into marketable tuber (>20 g)

Category wise potato yield (t ha^{-1}):

On the basis of the size of the tuber Cane (25-45 mm), Chips (45-75 mm) and French fry (>75 mm) potato tuber was graded.

Firmness (N):

The fresh potato tubers were cut into several slices to take the firmness reading by a Texture Analyzer, Sun Rheometer Compac 100 (Sun scientific co. Ltd, Japan). The reading seems that, how much pressure is taken by the potato tuber slice to make it chips. Each measurement was conducted on 10 potato slices as described by (Vliet *et al.*, 2007).

Total dry matter (%):

The total dry matter was recorded by drying parts (80^{0}C ± 2) for 72 hours and calculated from summation of leaves, stem, tuber and roots weights was taken in an electronic balance.

Specific Gravity (g cc^{-1}):

It was measured by using the following formula

$$\text{Specific gravity } = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$$

Skin color and flesh color of tuber:

Color is an important quality attribute which influences the acceptability of fried products (Nourian *et al.*, 2003). Color was measured with a color spectrophotometer NF333 (Nippon Denshoku, Japan) using the CIE Lab L*. a and b* color scale. The L* value is the lightness parameter indicating degree of lightness of the sample; it varies from 0=black (dark) to 100 = white (light). The 'a* which is the chromatic redness parameter, whose value means tending to red color when positive (+) and green color when negative (-). The 'b*' is yellowness chromatic parameter corresponding to yellow color when it is positive (+) and blue color when it is negative (-). Each sample consisted of 10 slices, each of which was measured thrice.

Polyphenol (GA mg 100 g^{-1} FW):

The content of total phenolic compounds was determined spectrophotometrically according to Folin-Ciocalteu method (Singleton *et al*., 1999) with slight modification.

Starch (%):

Starch content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). Phosphate buffer solution was prepared through diluted 0.74 g NaH_2PO_4 $2H_2O$ and 0.09 g Na_2HPO_4 $12H_2O$ into 100 ml Distilled water. Added 0.1 g Enzyme (Amyloglucosidase) and mixed well. Then it kept at -20°C for the preservation. The residue remained after extraction for sugar was washed for several times with water to ensure that there was no more soluble sugar in the residues. After that using tap water and mark up to 250 ml beaker. Stirred well on a magnetic stirrer. Then 0.5 mL solution was taken from the beaker during stirring into 3 test tubes. Boil the test tubes for 10 min at 100°C. Add 1 ml Amyloglucosidase solution, mix well, and heat at 50-60°C for 2 hours in hot water. After cooling, add 0.5 ml Copper solution, mix well, heat at 100°C for 10 min., cool in tap water, add 0.5 ml Nelson solution, mix well, add 7 ml distilled water, mix well (Final volume = 9.5 ml), and measure the absorbance at 660 nm (Abs). Calculate starch content using the glucose standard curve. Calculated value expressed as mg per g Fresh Weight (mg g^{-1} FW).

Calculation of starch content, Starch = Abs x 0.9

Reducing sugar and non-reducing sugar:

Extraction of sugar:

For the analysis of sugar content like reducing sugar (glucose) and non-reducing sugar (sucrose) potato flesh was extracted, for each extraction, 1 g fresh sample of chopped potato was taken from uniform tuber samples and smashed well in a motor. Sugar was extracted using 5 ml of 80% ethanol heat at 80°c for 30 min using a dry block heat bath and the extracts was centrifuged at 5000 rpm for 10 min and decanted the supernatant. 8 ml. 80% EtOH, was added and it was repeated 4 and 5 times in total. All the supernatants were mixed well and the final volume was made up to 25 ml using 80% EtOH. The residue is used for starch analysis.

Reducing Sugar (mg g^{-1}FW):

Reducing sugar was estimated by the photometric adaptation of the Somogyi method (Nelson, 1944) with some modification. Copper solution and Nelson reagent and standard glucose solution (0.5 mL) were used. 3 ml sample solution was put into a small glass container. Then it was completely dried up on an electric heater, 3 mL distilled water was added and then mixed well. Then 0.5 ml solution was taken from that, two times and was put in different test tubes. In one test tube, 0.5 mL Copper solution was added and was boiled (100° C) for 10 min. After boiling, immediately the test tube was cooled in tap water. 0.5 mL Nelson reagent in the test tube was added, and mixed them well. After 20 min, 8 mL distilled water was added and mixed well (Total volume = 9.5 mL). After that the absorbance at 660 nm (Abs1) was measured and the reducing sugar content was calculated. Calculated value expressed as mg per g Fresh Weight (mg g^{-1} FW).

Non-Reducing Sugar (mg g^{-1}FW):

Non-reducing sugar content of tubers was determined by Somogyi-Nelson method (Nelson, 1944). 0.2 ml Invertase solution (1,000 U/0. 1 mL) was diluted with 50 ml distilled water, and add one drop of Vinegar. 0.5 ml. solution, which was left during reducing sugar determination, was put into a test tube, Then 0.5 ml diluted Invertase solution (20 Unit/0.5 mL) was added and incubated for 30 min at ambient temperature and then .05ml Copper solution was added and boiled (100° C) for 10 min. After boiling, immediately the test tubes were cooled in tap water. 0.5 mL Nelson reagent in the test tube was added, and mixed them well. After 20 min, 8 ml distilled water was added and mixed well (Total volume = 9.5 mL). After that the absorbance at 660 nm (Abs2) was measured and the reducing sugar content was calculated. Calculated value expressed as mg per g Fresh Weight (mg g^{-1} FW).

Antioxident (Trolox µ Mol 100 g^{-1} FW):

A number of methods are used to determine the radical scavenging effects of antioxidants. The DPPH method is a preferred method because it is fast, easy and reliable and does not require a special reaction and device. DPPH is a stable, synthetic radical that does not disintegrate in water, methanol, or ethanol. The free radical scavenging activities of extracts depend on the ability of antioxidant compounds to lose hydrogen and the structural conformation of these components (Shimada *et al.*, 1992; Fukumoto and Mazza, 2000). The DPPH free radical, which is at its maximum wavelength at 517 nm, can easily receive an electron or hydrogen from antioxidant molecules to become a stable diamagnetic molecule (Soares *et al*., 1997). Total antioxidant capacity of fresh potatoes was quantified using the DPPH (2, 2-diphenyl-1-picrylhydrazyl) method (Hatano *et al.*, 1988; Ferreira *et al.*, 2007; Cheel *et al*., 2005). Each mixture was kept in the dark for 30 min and the absorbance was measured in spectrophotometer at 517 nm wave length against a blank (Shimada *et al*., 1992). All the values of antioxidant were expressed as Trolox equivalent µ Mol per 100 g fresh weight (Trolox µ Mol 100 g^{-1} FW) using a nonlinear regression algorithm from Trolox standard curve.

3.9 Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 software .The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

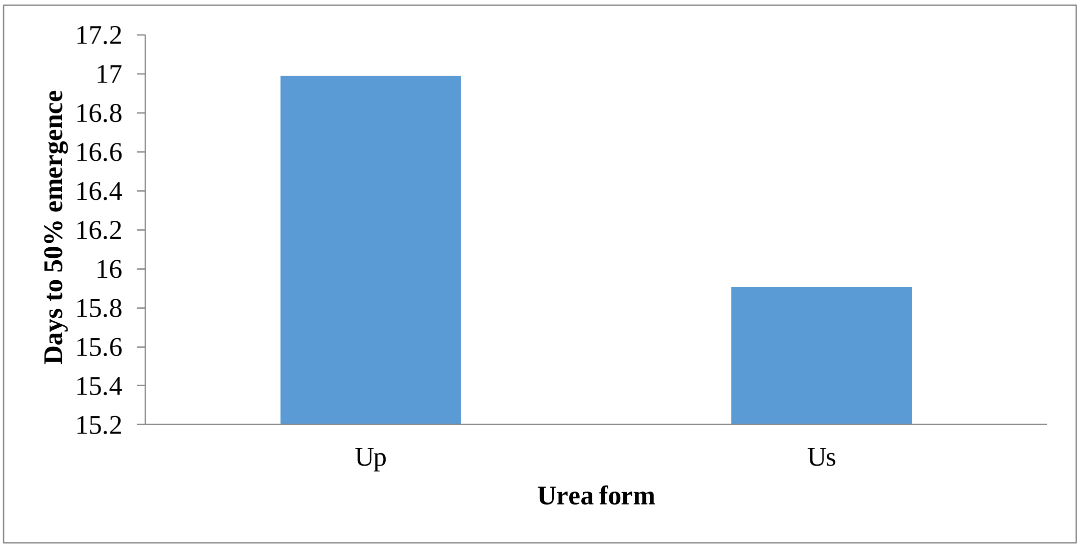
The data on different growth, yield characters and qualities of potato were recorded to find out the suitable urea forms and biochar levels on yield and quality of potato. The results have been presented and discussed, and possible explanation has been given under the following headings:

4.1 Crop growth characters

4.1.1 Days to 50% emergence

4.1.1.1 Effect of urea forms

Different urea forms showed significant effect on emergence of potato (Figure 1). From the experiment result revealed that maximum days to 50 % emergence of potato (16.989) was observed in Prilled Urea (U_p), whereas minimum days to 50 % emergence of potato (15.906) was observed in Urea Super Granule (U_S) This might be due to uninterrupted and continuous long time supply of N using USG which favors higher N uptake by the crop.

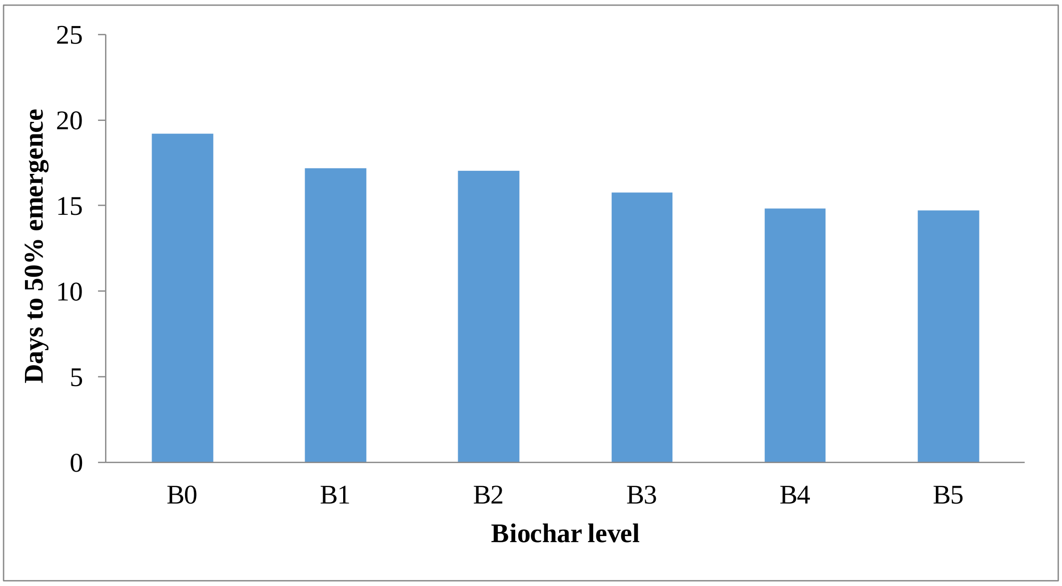


Up- Prilled urea, Us- Urea Super granules

Figure 1: Effect of urea forms on days to 50% emergence of potato (LSD $_{(0.05)}$ = 0.2058).

4.1.1.2 Effect of biochar

Biochar is a charcoal-like substance that's made by burning organic material from agricultural and forestry wastes (also called biomass) in a controlled process called pyrolysis. Although it looks a lot like common charcoal, biochar is produced using a specific process to reduce contamination and safely store carbon. From the experiment, result revealed that different biochar levels showed significant effect on emergence of potato (Figure 2). Result exhibited that the maximum days to 50 % emergence of potato (19.183) was observed in B_0 treatment whereas minimum days to 50 % emergence of potato (14.717) was observed in B_5 treatment which was statistically similar with B_4 (14.834) treatment followed by B_3 (15.750) treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 2: Effect of biochar levels on days to 50% emergence of potato (LSD $_{(0.05)}$ = 1.9072).

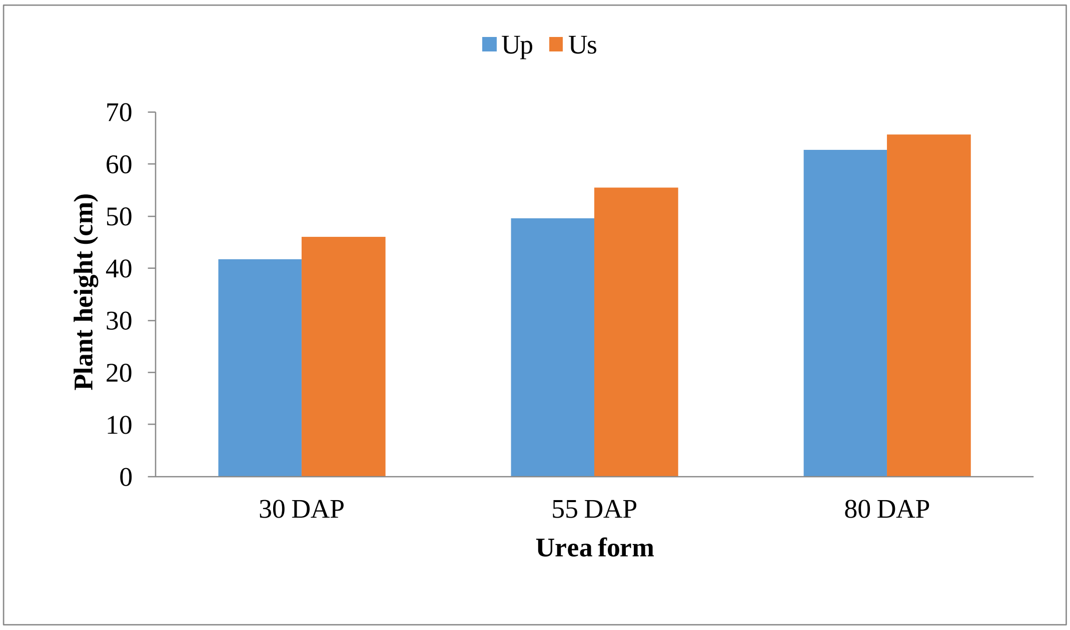
4.1.1.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on emergence of potato (Table 1). From the experiment result showed that the maximum days to 50 % emergence of potato (19.967) were observed in U_pB_0 treatment combination whereas minimum days to 50 % emergence of potato (14.467) were observed in U_sB_5 treatment combination

4.1.2 Plant Height

4.1.2.1 Effect of urea forms

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Different urea forms showed significant effect on plant height of potato (Figure 3). From the experiment result revealed that the maximum plant height of potato (46.050 ,55.489 and 65.711 cm at 30, 55 and 80 DAP) was observed in U_S treatment (Urea Super Granule) whereas minimum plant height of potato (41.717 , 49.589 and 62.695 cm at 30, 55 and 80 DAP) was observed in U_p treatment (Prilled Urea). The prolonged supply of N by the USG may be the cause for higher plant height in USG treated plants.

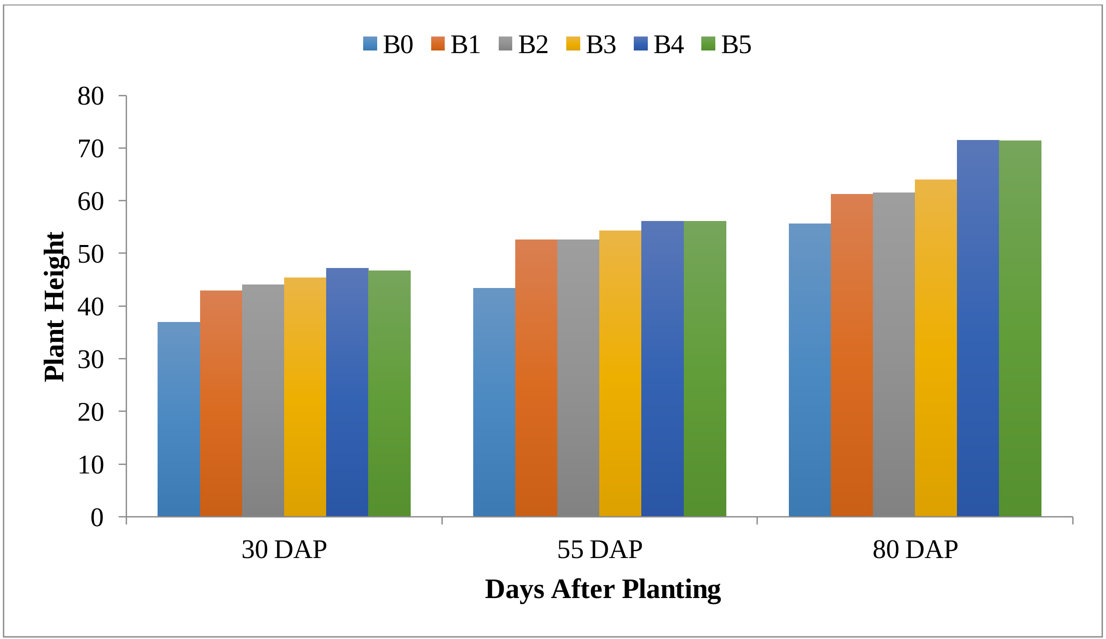


Up- Prilled urea, Us- Urea Super granules

Figure 3: Effect of urea forms on plant height of potato (LSD $_{(0.05)}$ = 1.9232, 1.9441 and 2.7666 at 30, 55 and 80 DAP).

4.1.2.2 Effect of biochar

Different biochar levels showed significant effect on plant height of potato at different days after planting (Figure 4). From the experiment result showed that the maximum plant height (47.217 cm) was observed in B_4 treatment at 30 DAP, at 55 DAP (56.150 cm) from B_5 treatment and at 80 DAP (71.517 cm) was observed from B_4 treatment which was statistically similar with B_5, B_3 and B_2 treatment at 30 DAP; with all others treatment except B_0 treatment at 55 DAP and with B_4 treatment at 80 DAP. Whereas minimum plant height (36.934, 43.417 and 55.584 cm at 30, 55 and 80 DAP) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 4: Effect of biochar levels on plant height of potato ($LSD_{(0.05)}$= 3.7957, 3.8755 and 5.5647 at 30, 55 and 80 DAP).

4.1.2.3 Combined effect of urea forms and biochar levels

Only at 55 DAP, different urea forms with biochar levels showed significant effect on plant height of potato (Table 1). At 30, 55 and 80 DAP maximum plant height (49.433, 60.333 and 74.233 cm) was observed from U_sB_5 treatment combination which was statistically similar with U_sB_4 treatment combination followed by U_sB_3,

U_sB_2, and U_sB_1 treatment combination at 55DAP. Whereas minimum plant height (35.30, 42.367 and 53.867 cm at 30, 55 and 80 DAP) was observed from U_pB_0 treatment combination which was statistically similar with U_sB_0 treatment combination at 55 DAP. The N uptake improvement in crops has been reported due to biochar amendment as a consequence of enhanced mineralization of native soil N (Chan *et al.*, 2008; Van *et al.*, 2009). For that higher biochar application along with Urea Super Granule application shows better plant height.

Table 1: Combined effect of urea forms and biochar levels on days to 50% emergence, plant height at different sampling dates of potato.

Treatment	Days to 50% emergence	Plant height at		
		30 DAP	55 DAP	80 DAP
U_pB_0	19.967	35.300	42.367 g	53.867
U_p B_1	17.900	40.600	50.233 de	59.633
U_p B_2	17.567	41.933	49.367 ef	61.400
U_p B_3	16.433	43.833	51.167 cde	63.367
U_p B_4	15.100	44.567	52.433 b-e	69.367
U_p B_5	14.967	44.067	51.967 cde	68.533
U_s B_0	18.400	38.567	44.467 fg	57.300
U_s B_1	16.467	45.233	55.000 a-d	62.867
U_s B_2	16.467	46.233	55.867 abc	61.600
U_s B_3	15.067	46.967	57.433 ab	64.600
U_s B_4	14.567	49.867	59.833 a	73.667
U_s B_5	14.467	49.433	60.333 a	74.233
LSD $_{(0.05)}$	NS	NS	5.4808	NS
CV(%)	9.63	7.18	6.12	7.20

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

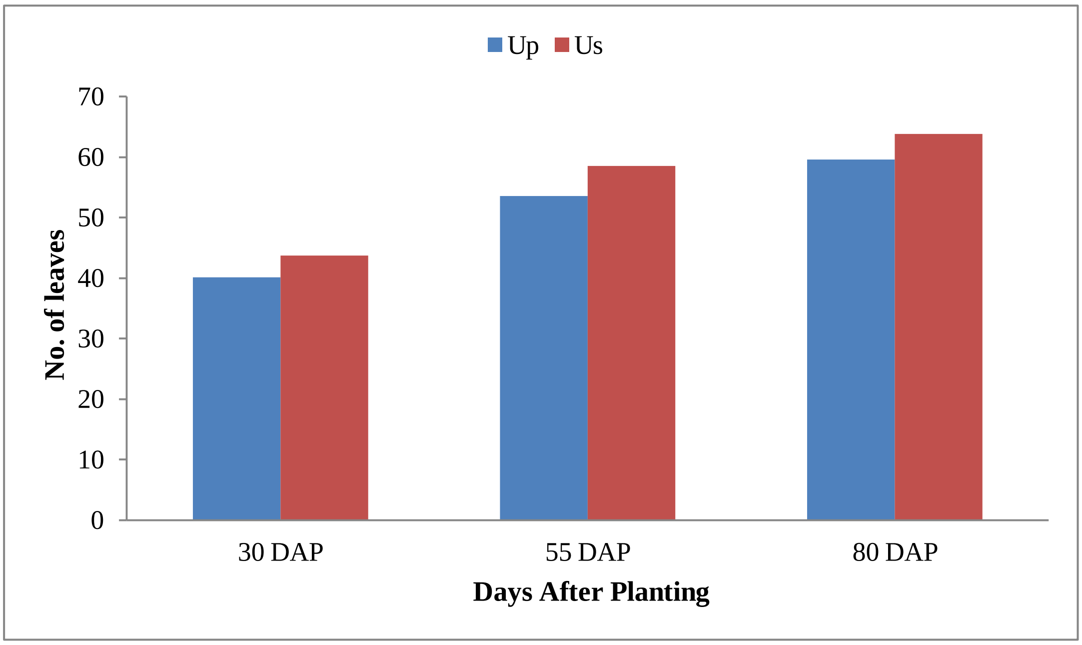
NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.1.3 Number of leaves

4.1.3.1 Effect of urea forms

Different urea forms showed significant effect on leaf number of potato (Figure 5). From the experiment result revealed that the maximum number of leaves of potato (43.695, 58.544 and 63.826 at 30, 55 and 80 DAP) was observed in U_S treatment (Urea Super Granule) whereas the minimum number of leaves of potato (40.062, 53.498 and 59.60 at 30, 55 and 80 DAP) was observed in U_p treatment (Prilled Urea).

The possible reason is that as USG placed at deeper zone where limited number of nitrifying bacteria present at the premise of the USG and convert a limited portion of urea to NO_3^- which is utilized by the plant efficiently and reduced N loss. As the Urea super granule treated plant get adequate nitrogen supply so their vegetative growth is better than prilled urea and thus the number of leaves in U_s is greater.

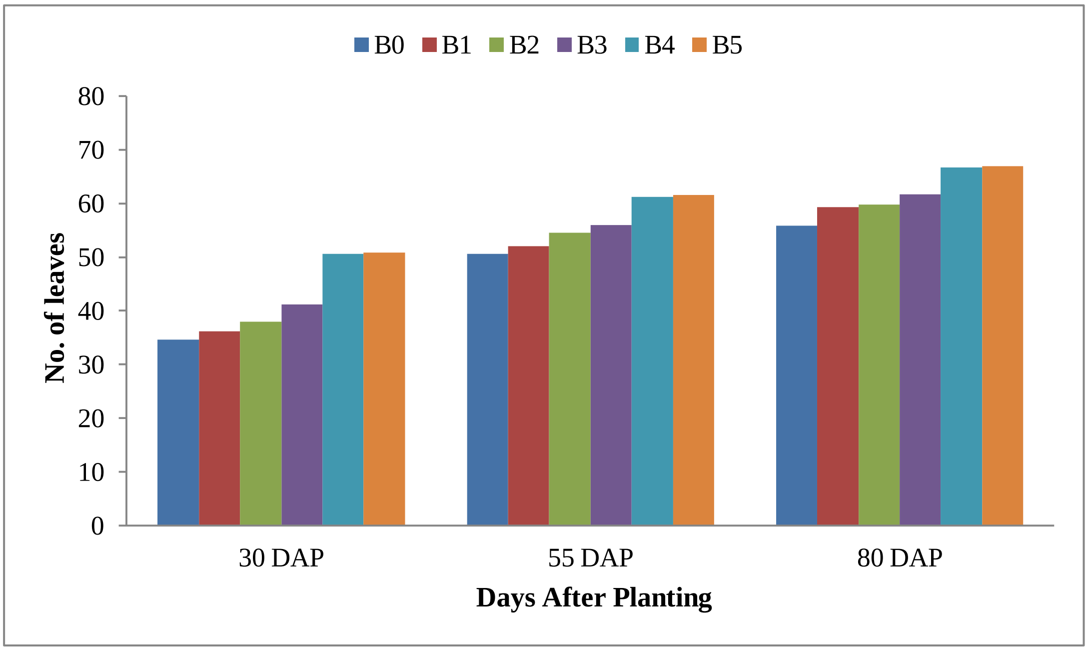


Up- Prilled urea, Us- Urea Super granules

Figure 5: Effect of urea forms on number of leaves of potato (LSD $_{(0.05)}$ = 2.8914, 0.1018 and 1.1167 at 30, 55 and 80 DAP).

4.1.3.2 Effect of biochar

Different biochar levels showed significant effect on leaf number of potato at different days after planting (Figure 6). From the experiment result showed that the maximum number of leaves of potato (50.810, 61.567 and 66.967 at 30, 55 and 80 DAP) was observed from B_5 treatment which was statistically similar with B_4 treatment at 30, 55 and 80 DAP; with B_3 treatment at 55 and 80 DAP. Whereas the minimum number of leaves of potato (34.60, 50.665 and 55.811 at 30, 55 and 80 DAP) was observed in B_0 treatment which was statistically similar with B_1 treatment followed by B_2 treatment at 30, 55 and 80 DAP; with B_3 treatment at 30 DAP.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 6: Effect of biochar levels on number of leaves of potato (LSD $_{(0.05)}$ = 4.4594, 5.5665 and 6.1818at 30, 55 and 80 DAP).

4.1.3.3 Combined effect of urea forms and biochar levels

Different urea forms with biochar levels showed non significant effect on number of leaves of potato (Table 2). Maximum number of leaves (55.037 and 66.600 at 30, 55 DAP) was observed from U_sB_5 treatment combination and maximum number of leaves (69.933) at 80DAP from U_sB_4 treatment combination. Whereas the minimum number of leaves of potato (34.333, 49.867 and 54.200 at 30, 55 and 80 DAP) was observed from U_pB_0 treatment combination.

Table 2: Combined effect of urea forms and biochar levels on leaves number of potato

Treatment	Leaf number at		
	30 DAP	55 DAP	80 DAP
U_pB_0	34.333	49.867	54.200
U_pB_1	35.487	51.421	58.133
U_pB_2	37.333	53.103	58.333
U_pB_3	40.287	53.267	59.133
U_pB_4	46.350	56.800	63.467
U_pB_5	46.583	56.533	64.333
U_sB_0	34.867	51.462	57.422
U_sB_1	36.800	52.600	60.533
U_sB_2	38.667	56.067	61.200
U_sB_3	42.000	58.800	64.267
U_sB_4	54.800	65.733	69.933
U_sB_5	55.037	66.600	69.600
LSD $_{(0.05)}$	NS	NS	NS
CV(%)	8.84	8.25	8.32

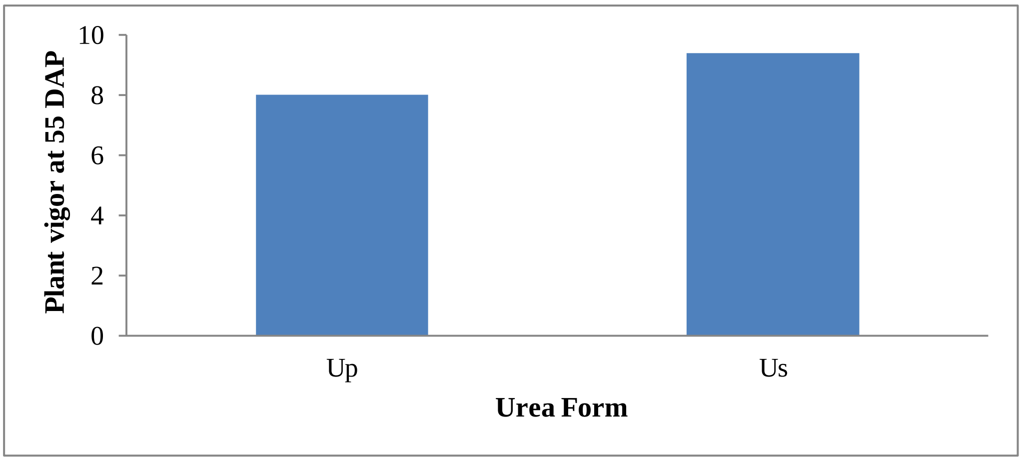
In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.1.4 Plant vigor (1-10) at 55 DAP

4.1.4.1 Effect of urea forms

Significant variation was observed in plant vigor at 55 DAP due to application of different urea forms in the field (Figure 7). From the experiment result exhibited that the maximum plant vigor at 55 DAP (9.3989) was observed in U_s treatment whereas that the minimum plant vigor at 55 DAP (8.0272) was observed in U_p treatment. Mukherjee (1986) reported that the USG with deep placement provided a zone of concentrated urea solution where the denitrifying bacteria cannot enter and therefore N is left at the root zone for uptake by the plants. So the USG treated plant shows better vigor than the prilled one.

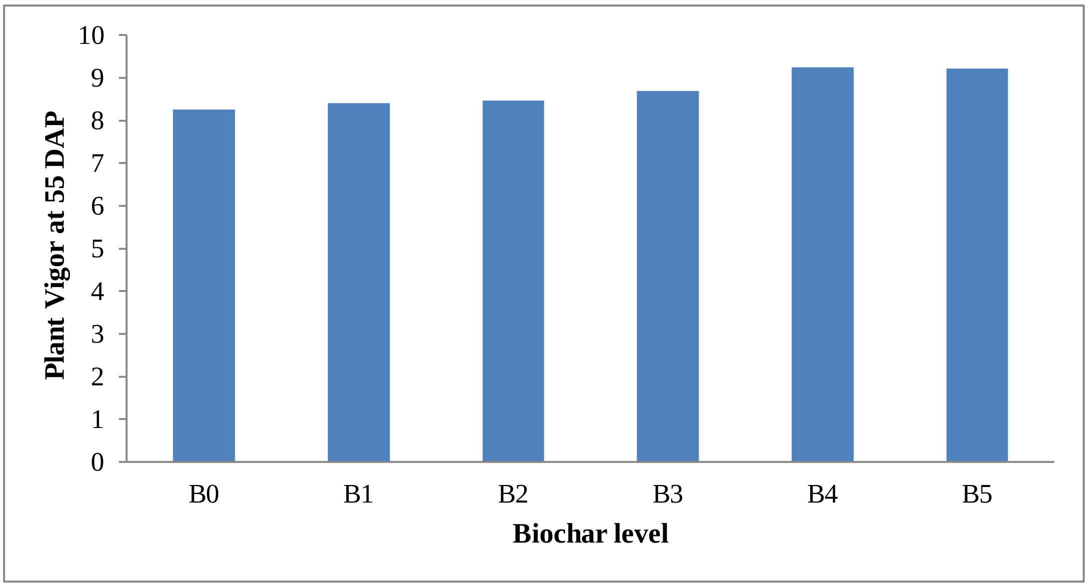


Up- Prilled urea, Us- Urea Super granules

Figure 7: Effect of urea forms on Plant vigor (1-10) at 55 DAP (LSD $_{(0.05)}$ = 1.1521).

4.1.4.2 Effect of biochar

Significant variation was observed in plant vigor at 55 DAP due to application of different biochar levels in the field (Figure 8). From the experiment result exhibited that the maximum plant vigor at 55 DAP (9.2467) was observed in B_4 treatment which was statistically similar with B_5 treatment whereas the minimum plant vigor at 55 DAP (8.2567) was observed in B_0 treatment which was statistically similar with B_1 treatment followed by B_2 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 8: Effect of biochar levels on Plant vigor (1-10) at 55 DAP (LSD $_{(0.05)}$ = 0.2227).

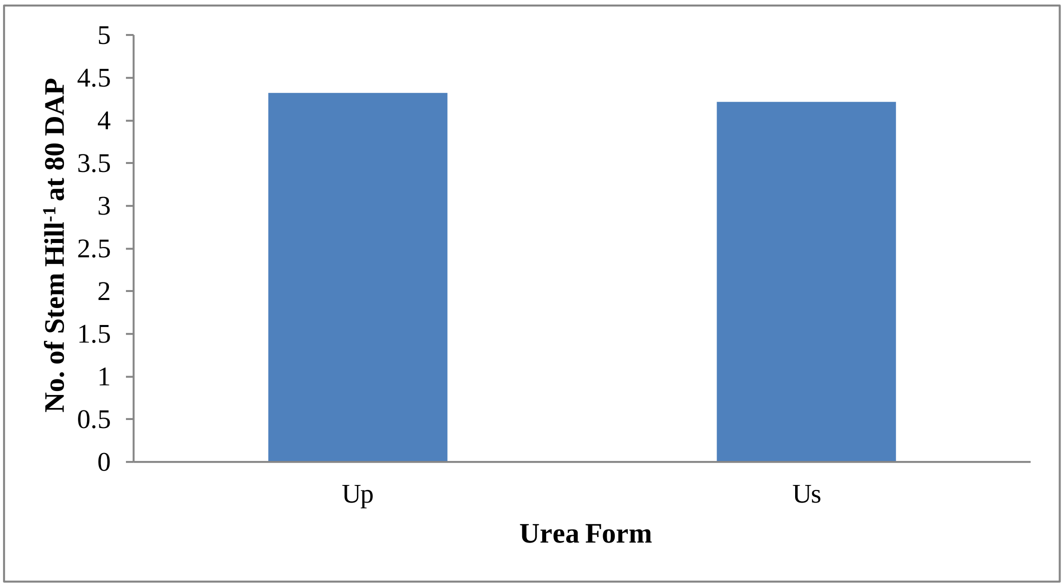
4.1.4.3 Combined effect of urea forms and biochar levels

Different urea forms with biochar levels showed non significant effect on plant vigor at 55 DAP of potato (Table 3). Maximum plant vigor at 55 DAP (10.0) was observed from U_sB_4 treatment combination. Whereas the minimum plant vigor at 55 DAP of potato (7.590) was observed from U_pB_0 treatment combination

4.1.5 Number of stem hill^{-1} at 80 DAP

4.1.5.1 Effect of urea forms

Number of stem hill^{-1} at 80 DAP showed non significant effect on potato due to application of different urea form in the field (Figure 9). From the experiment result exhibited that the maximum number of stem hill^{-1} at 80 DAP (4.3225) was observed in U_p treatment whereas that the minimum number of stem hill^{-1} at 80 DAP (4.2223) was observed in U_s treatment

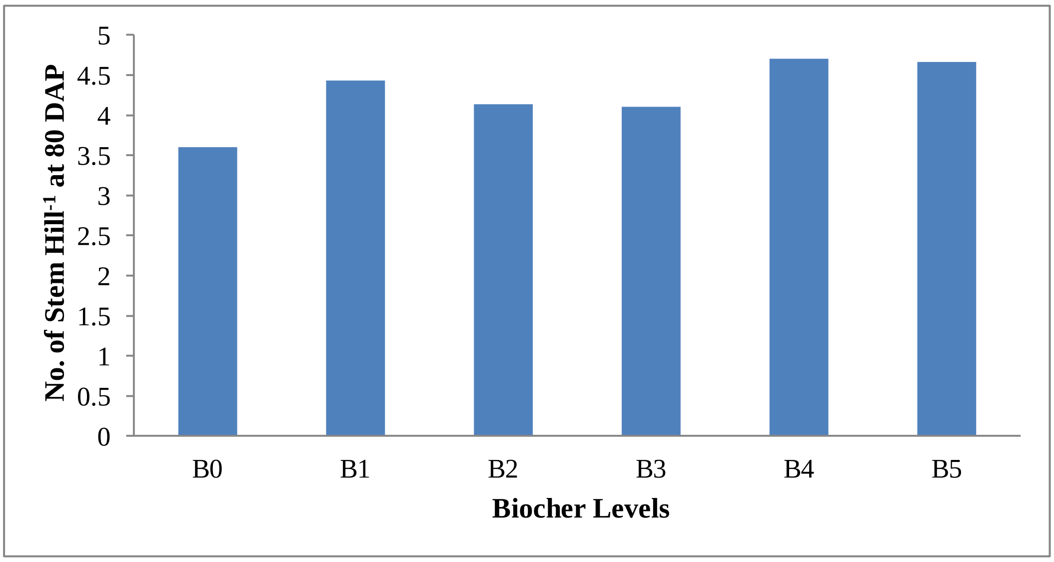


Up- Prilled urea, Us- Urea Super granules

Figure 9: Effect of urea forms on Number of stem hill^{-1} at 80 DAP (LSD $_{(0.05)}$ = NS).

4.1.5.2 Effect of biochar

Biochar levels showed significant effect on number of stem hill^{-1} at 80 DAP of potato (Figure 10). From the experiment result showed that the maximum number of stem hill^{-1} at 80 DAP (4.7002) was observed in B_4 treatment which was statistically similar with all others treatment except B_0, B_2 and B_3 treatments whereas the minimum number of stem hill^{-1} at 80 DAP (3.6000) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 10: Effect of biochar levels on number of stem hill^{-1} at 80 DAP (LSD$_{(0.05)}$= 0.4843).

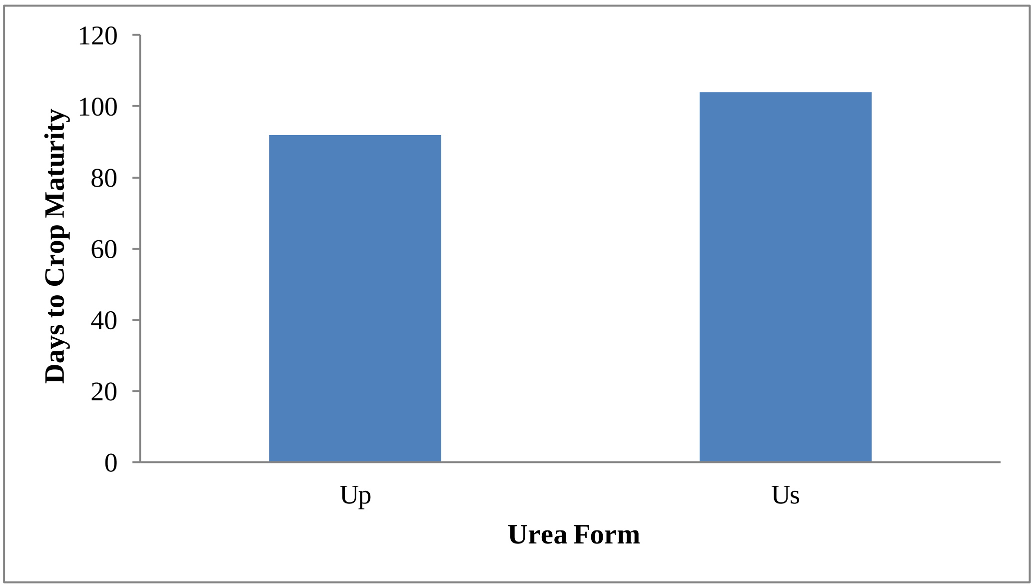
4.1.5.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect on number of stem hill^{-1} at 80 DAP of potato (Table 3). From the experiment result exposed that the maximum number of stem hill^{-1} at 80 DAP (5.0003) of potato was observed from U_p B_1 treatment combination which was statistically similar with U_sB_4, U_pB_5, U_pB_4, U_sB_5 and U_sB_3 treatment combination whereas minimum number of stem hill^{-1} at 80 DAP (3.5330) was observed from U_sB_0 treatment combination which was statistically similar with U_pB_0, U_pB_3, U_sB_1, U_pB_2, and U_sB_2 treatment combination

4.1.6 Days to crop maturity

4.1.6.1 Effect of urea forms

Different urea forms showed significant effect on crop maturity of potato (Figure 11). From the experiment result revealed that the maximum days to crop maturity of potato (required 104.0 days) was observed in U_S treatment (Urea Super Granule) whereas the minimum days to crop maturity of potato (required 91.83 days) was observed in U_p treatment (Prilled Urea).

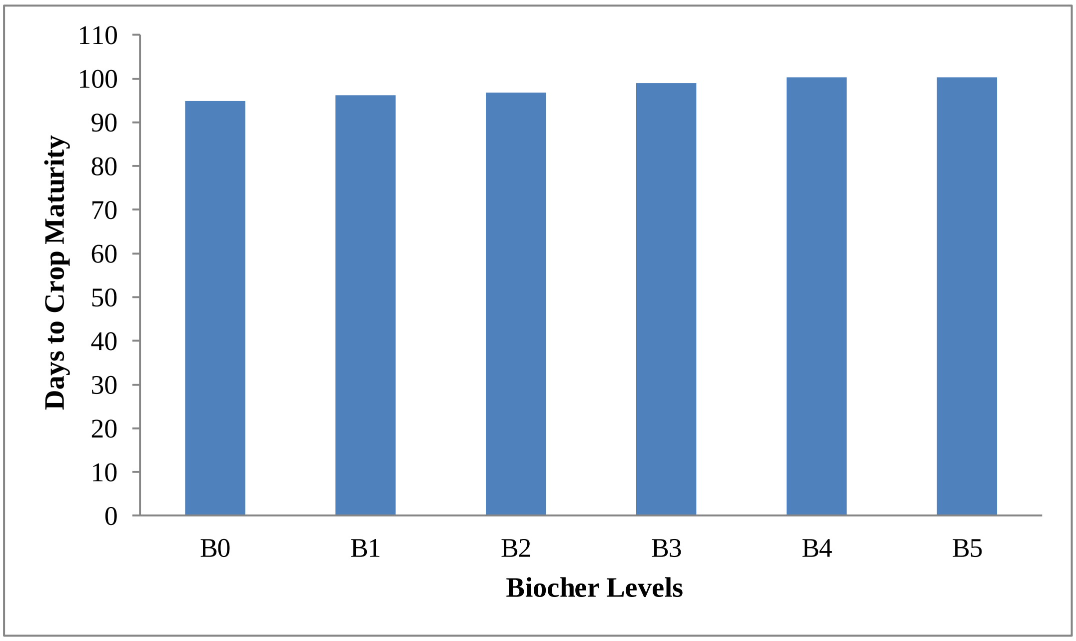


Up- Prilled urea, Us- Urea Super granules

Figure 11: Effect of urea forms on days to crop maturity of potato (LSD $_{(0.05)}$ = 3.6094).

4.1.6.2 Effect of biochar

Biochar levels showed significant effect on crop maturity of potato (Figure 12). From the experiment result showed that the maximum days to crop maturity of potato (required 100.33 days) was observed in B_5 treatment which was statistically similar with B_4 treatments whereas the minimum days to crop maturity of potato (required 94.83 days) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 12: Effect of biochar levels on days to crop maturity of potato ($LSD_{(0.05)}$ = 1.1425).

4.1.6.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on crop maturity of potato (table 3). From the experiment result exposed that the maximum days to crop maturity of potato (required 106.67 days) was observed from U_sB_5 treatment combination whereas minimum days to crop maturity of potato (required 88.67 days) was observed from U_pB_0 treatment combination.

Table 3: Combined effect of urea forms and biochar levels on plant vigor, number of stem hill^{-1} at 80 DAP and days to crop maturity of potato.

Treatment	Plant vigor (1-10) At 55 DAP	Number of stem hill^{-1} at 80 DAP	Days to crop maturity
U_pB_0	7.590	3.6670 f	88.67
U_pB_1	7.753	5.0003 a	90.67
U_pB_2	7.883	4.0670 c-f	91.00
U_pB_3	7.980	3.8003 ef	92.67
U_pB_4	8.493	4.5333 abc	94.00
U_pB_5	8.463	4.8670 a	94.00
U_sB_0	8.923	3.5330 f	101.00
U_sB_1	9.050	3.8667 def	101.67
U_sB_2	9.053	4.2003 b-f	102.67
U_sB_3	9.400	4.4000 a-e	105.33
U_sB_4	10.000	4.8670 ab	106.67
U_sB_5	9.967	4.4670 a-d	106.67
LSD $_{(0.05)}$	NS	0.6849	NS
CV(%)	2.12	9.41	1.97

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

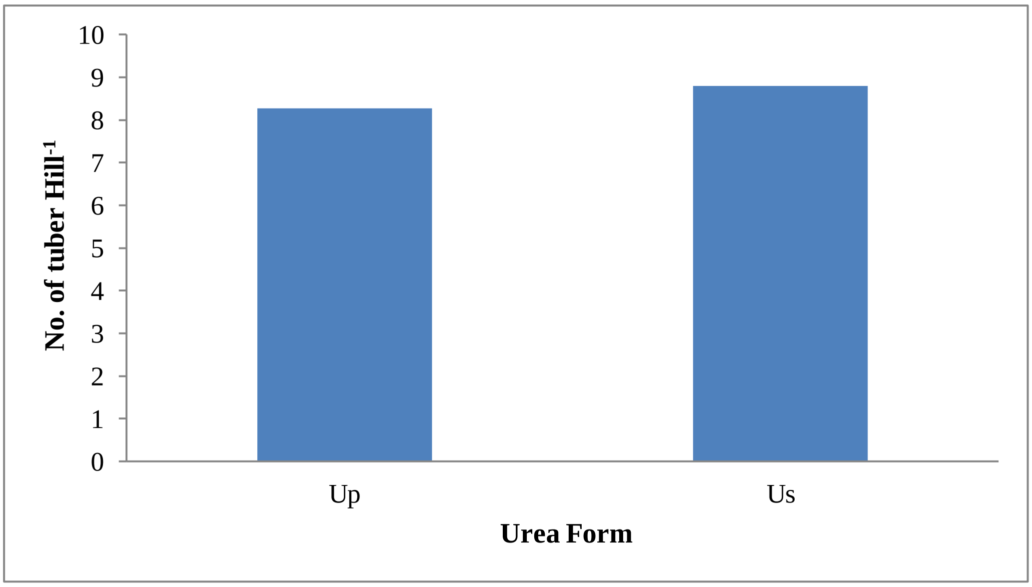
NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.2 Yield and yield components

4.2.1 No of tuber hill^{-1}

4.2.1.1 Effect of Urea forms

Different urea forms showed significant effect on number of tuber hill^{-1} of potato (Figure 13). From the experiment result revealed that the maximum number of tuber hill^{-1} of potato (8.7921) was observed in U_S treatment (Urea Super Granule) whereas the minimum number of tuber hill^{-1} of potato (8.2713) was observed in U_p treatment (Prilled Urea). Availability of more nitrogen from USG during tuber formation and development that contributed to higher number of tuber per hill.

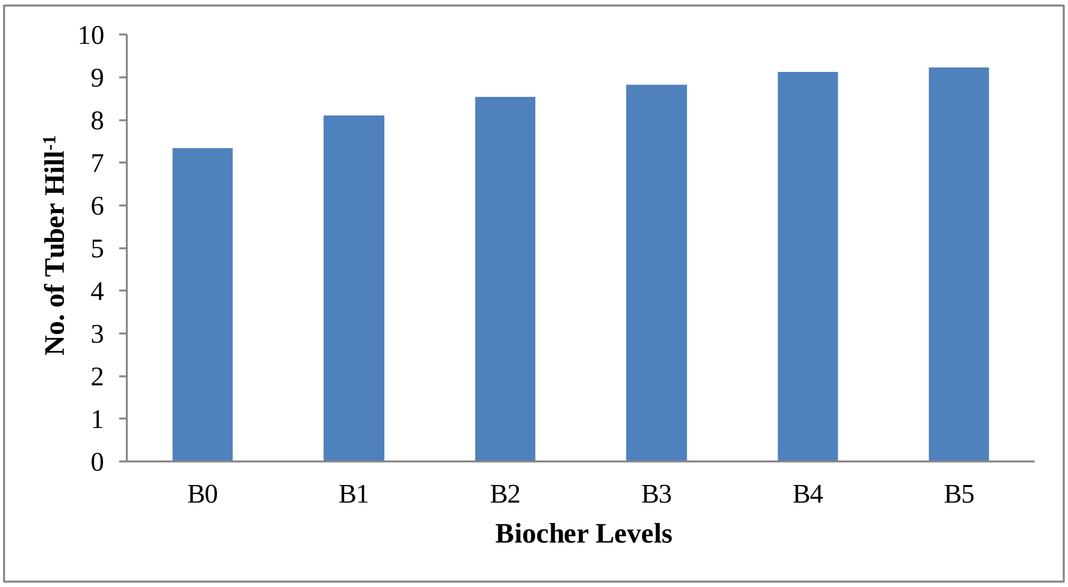


Up- Prilled urea, Us- Urea Super granules

Figure 13: Effect of urea forms on number of tuber hill^{-1} of potato (LSD $_{(0.05)}$ = 0.3386).

4.2.1.2 Effect of biochar

Biochar levels showed significant effect on number of tuber hill^{-1} of potato (Figure 14). From the experiment result showed that the maximum number of tuber hill^{-1} of potato (9.2292) was observed in B_5 treatment which was statistically similar with B_4 treatments followed by B_3 treatments whereas the minimum number of tuber hill^{-1} of potato (7.3466) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 14: Effect of biochar levels on number of tuber hill^{-1} of potato ($LSD_{(0.05)}$= 0.6320).

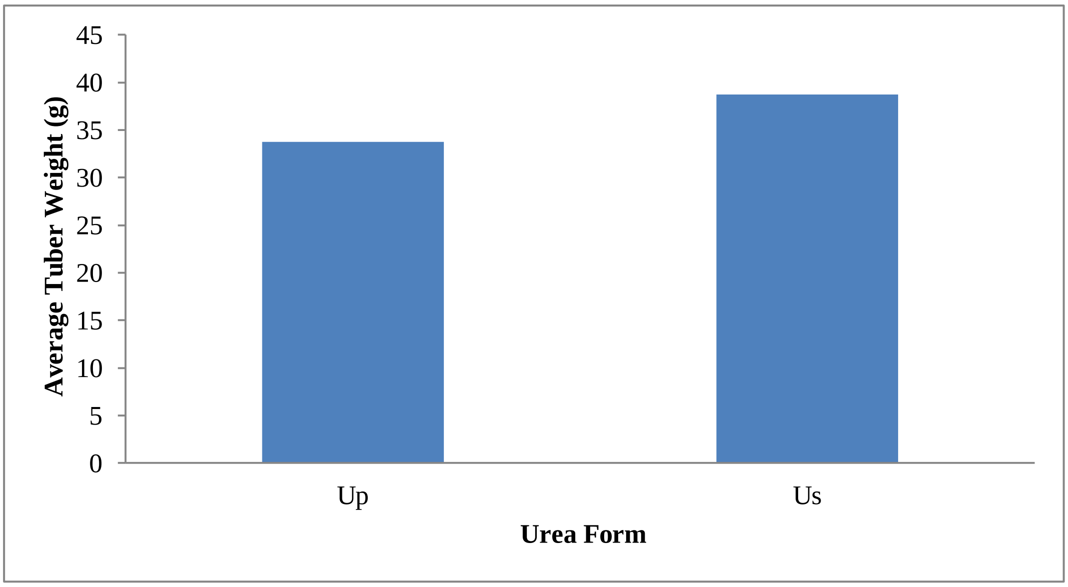
4.2.1.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on number of tuber hill^{-1} of potato (Table 4). From the experiment result exposed that the maximum number of tuber hill^{-1} of potato (9.5417) was observed from U_sB_5 treatment combination whereas the minimum number of tuber hill^{-1} of potato (7.2571) was observed from U_pB_0 treatment combination.

4.2.2 Average tuber weight (g)

4.2.2.1 Effect of urea forms

Different urea forms showed significant effect on average tuber weight (g) of potato (Figure 15). From the experiment result revealed that the maximum average tuber weight of potato (38.746 g) was observed in U_S treatment (Urea Super Granule) whereas the minimum average tuber weight of potato (33.743 g) was observed in U_p treatment (Prilled Urea). The low yield harvested from the control treatment is due to the insufficient supply of N, which leads to limitation of carbon assimilation and reduction in plant productivity (Shangguan *et al.*, 2000, Lawlor, 2002).

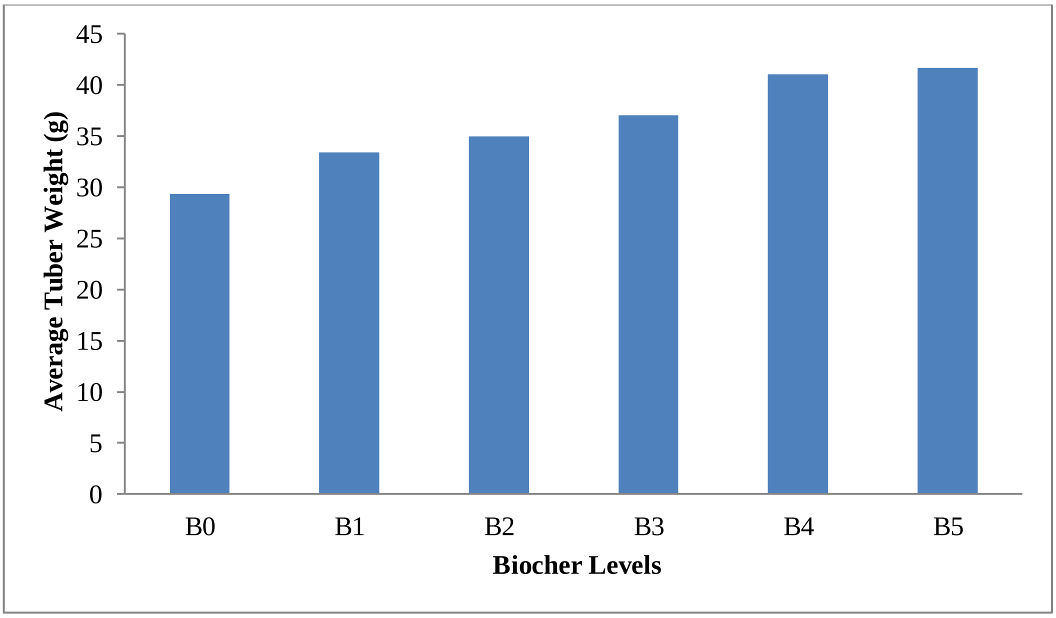


Up- Prilled urea, Us- Urea Super granules

Figure 15: Effect of urea forms on average tuber weight (g) of potato ($LSD_{(0.05)}$= 1.5787).

4.2.2.2 Effect of biochar

Biochar levels showed significant effect on average tuber weight (g) of potato (Figure 16). From the experiment result showed that the maximum average tuber weight of potato (41.691 g) was observed in B_5 treatment which was statistically similar with B_4 treatment. Whereas the minimum average tuber weight of potato (29.335 g) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 16: Effect of biochar levels on average tuber weight (g) of potato (LSD$_{(0.05)}$= 3.1717).

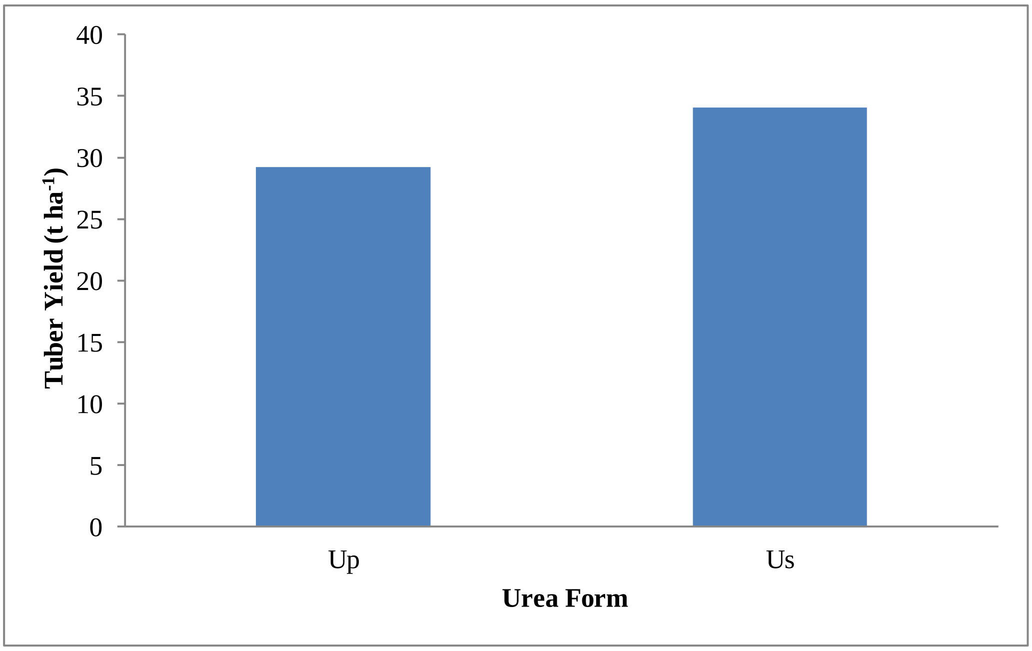
4.2.2.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on average tuber weight (g) of potato (Table 4). From the experiment result exposed that the maximum average tuber weight of potato (44.966 g) was observed from U_sB_5 treatment combination whereas the minimum average tuber weight of potato (26.526 g) was observed from U_pB_0 treatment combination.

4.2.3 Tuber yield (t ha^{-1})

4.2.3.1 Effect of urea forms

Different urea forms showed significant effect on tuber yield (t ha^{-1}) of potato (Figure 17). From the experiment result revealed that the maximum tuber yield of potato (34.084 t ha^{-1}) was observed in U_S treatment (Urea Super Granule) whereas the minimum tuber yield of potato (29.199 t ha^{-1}) was observed in U_p treatment (Prilled Urea). The higher yield obtained from USG might be due to decreased N emissions and volatilization loss from the deep placed N as USG which might have ensured continuous and uniform supply of available N for better crop uptake by the potato plant throughout the growing period. Higher nitrogen accumulation from urea super granule has increased the weight of individual tuber which might have given higher tuber yield per hectare.

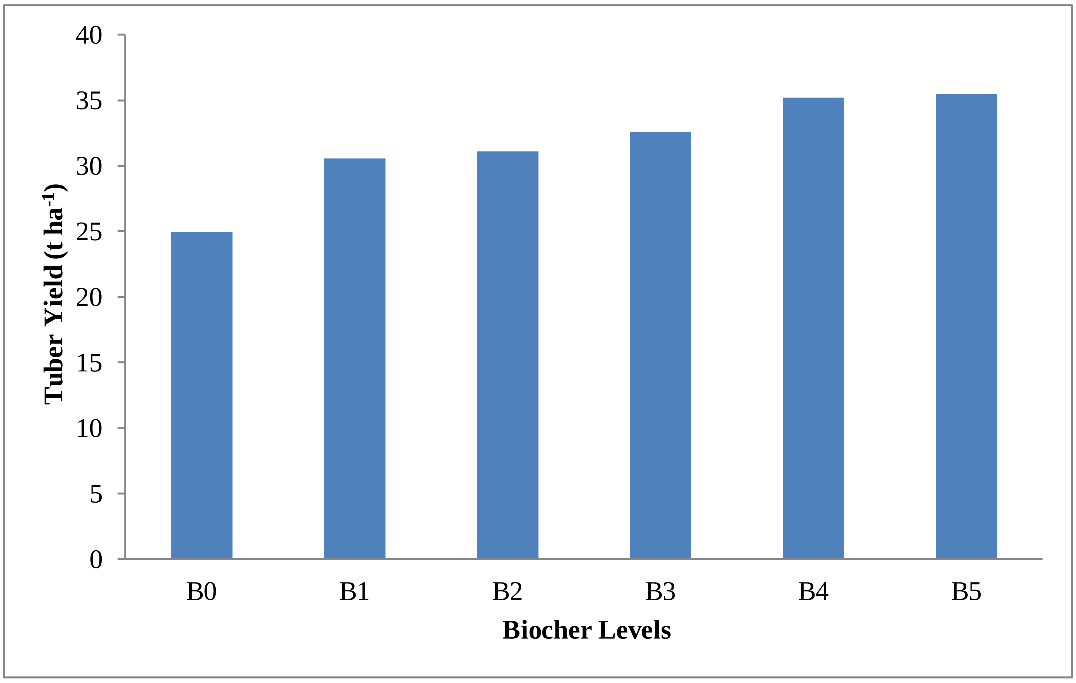


Up- Prilled urea, Us- Urea Super granules

Figure 17: Effect of urea forms on tuber yield (t ha^{-1}) of potato ($LSD_{(0.05)}$= 1.4843).

4.2.3.2 Effect of biochar

Biochar levels showed significant effect on tuber yield (t ha^{-1}) of potato (Figure 18). From the experiment result showed that the maximum tuber yield of potato (35.489 t ha^{-1}) was observed in B_5 treatment which was statistically similar with B_4 treatment. Whereas the minimum tuber yield of potato (24.943 t ha^{-1}) was observed in B_0 treatment. The additional of biochar in the soil, modified the soil texture slightly from 'loamy sand' to 'sand', due to the presence of many larger particles in the range of sand in the biochar. However, the slight increase in clay-sized particles upon increasing the biochar application rates suggests increased surface area that could potentially affect the physiochemical activity of the soil positively (Githinji, 2014). Also application of biochar might have increased the tuber bulking than prilled urea which in turns increased the tuber yield per hectare. For this reason the tuber yield is increased with the increasing amount of biochar.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 18: Effect of biochar levels on tuber yield (t ha^{-1}) of potato ($LSD_{(0.05)}$= 2.9568).

4.2.3.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect on tuber yield (t ha^{-1}) of potato (Table 4). From the experiment result revealed that the maximum tuber yield of potato (37.981 t ha^{-1}) was observed from U_sB_5 treatment combination which was statistically similar with U_sB_4 treatment combination followed by U_sB_3 and U_sB_2 treatment combination whereas the minimum tuber yield of potato (24.691 t ha^{-1}) was observed from U_pB_0 treatment combination which was statistically similar with U_sB_0 treatment combination followed by U_p B_2 and U_pB_1 treatment combination. The application of 10% biochar along with urea which obviously may be due to less losses of nutrient particularly nitrogen because biochar holds NH_4+ after urea hydrolysis and makes unavailable to nitrifying and denitrifying microbes and thus leads less losses and more availability of nitrogen to plant such improvement was at its peak (Abbas *et al.*, 2017).

Table 4: Combined effect of urea forms and biochar levels on no. of tuber hill^{-1}, average tuber weight and tuber yield of potato.

Treatment	No of tuber hill^{-1}	Average tuber weight (g)	Tuber yield (t ha^{-1})
U_pB_0	7.2571	26.526	24.691 f
U_pB_1	7.9167	31.882	27.670 ef
U_pB_2	8.2639	33.194	26.982 ef
U_pB_3	8.4750	35.179	29.879 de
U_pB_4	8.7984	37.262	32.972 cd
U_pB_5	8.9167	38.416	32.997 cd
U_sB_0	7.4361	32.143	25.195 f
U_sB_1	8.2917	34.924	33.423 bcd
U_sB_2	8.8333	36.731	35.187 abc
U_sB_3	9.1944	38.918	35.263 abc
U_sB_4	9.4556	44.793	37.452 ab
U_sB_5	9.5417	44.966	37.981 a
LSD $_{(0.05)}$	NS	NS	4.1816
CV(%)	6.15	7.27	7.76

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.2.4 Yield of marketable potato (>20 g)

4.2.4.1 Effect of urea forms

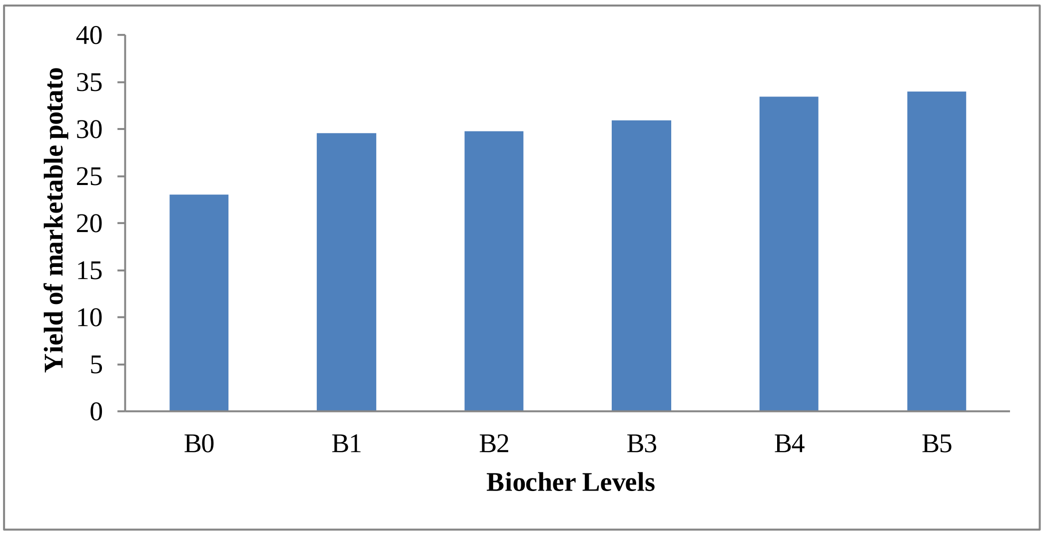
Yield of marketable potato (> 20 g) showed significant variation due to application of urea forms in the experimental field (Figure 19). From the experiment result expressed that the maximum yield of marketable potato (32.378 t ha^{-1}) was observed from U_S treatment whereas the minimum yield of marketable potato (27.906 t ha^{-1}) was observed in U_p treatment.

Up- Prilled urea, Us- Urea Super granules

Figure 19: Effect of urea forms on yield of marketable potato (>20 g) ($LSD_{(0.05)}$= 1.4491).

4.2.4.2 Effect of biochar

Biochar levels showed significant variation on yield of marketable potato (Figure 20). From the experiment result showed that the maximum yield of marketable potato (34.018 t ha^{-1}) was observed in B_5 treatment which was statistically similar with B_4 treatment. Whereas the minimum yield of marketable potato (23.042 t ha^{-1}) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 20: Effect of biochar levels on yield of marketable potato (>20 g) ($LSD_{(0.05)}$= 2.7746).

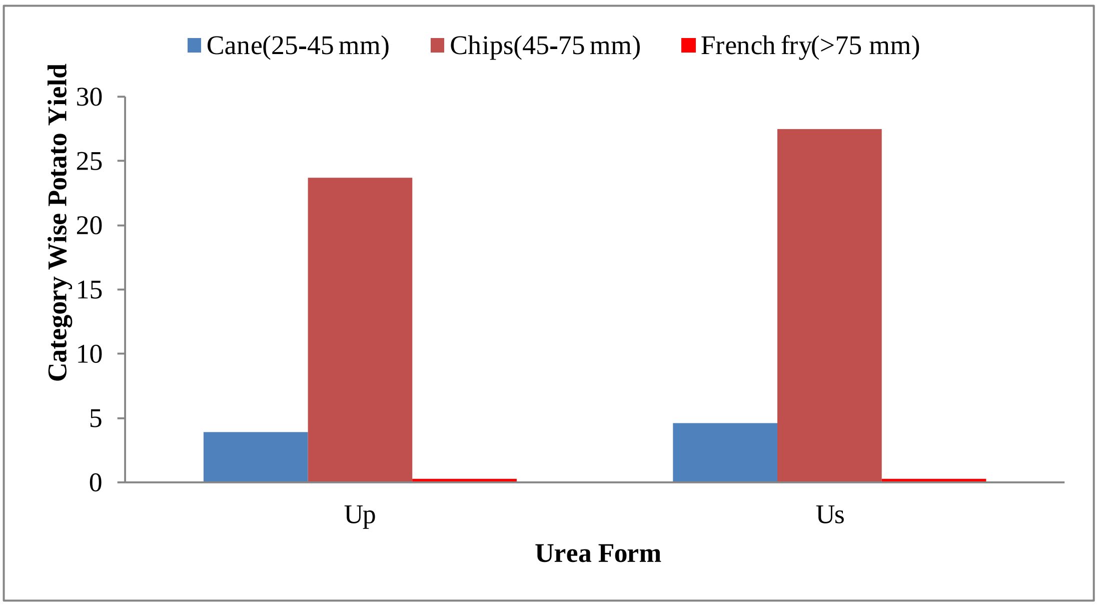
4.2.4.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect on yield of marketable potato (Table 5). From the experiment result revealed that the maximum yield of marketable potato (36.500 t ha^{-1}) was observed from U_sB_5 treatment combination which was statistically similar with U_sB_4 treatment combination followed by U_sB_3 and U_sB_2 treatment combination whereas the minimum yield of marketable potato (22.300 t ha^{-1}) was observed from U_pB_0 treatment combination which was statistically similar with U_sB_0 treatment combination.

4.2.5 Category wise potato yield (t ha^{-1})

4.2.5.1 Effect of Urea forms

In case of Category wise potato yield (t ha^{-1}) only at Chips (45-75 mm) potato yield (t ha^{-1}) showed significant variation than Cane (25-45 mm) and French fry (>75 mm) potato yield (t ha^{-1}) due to application of urea forms in the experimental field (Figure 21). From the experiment result revealed that the maximum category wise potato yield, {Cane (25-45 mm), Chips (45-75 mm) and French fry (>75 mm) onto 4.5987, 27.496 and 0.2829 t ha^{-1}} was observed from U_S treatment. Whereas minimum category wise potato yield, (Cane (25-45 mm), Chips (45-75 mm) and French fry (>75 mm) onto 3.9124, 23.702 and 0.2917 t ha^{-1}) was observed from U_p treatment. Applying nitrogen as super granule urea might have increased the growth of tubers resulted greater tuber size which might have given different sizes for different processing purposes.



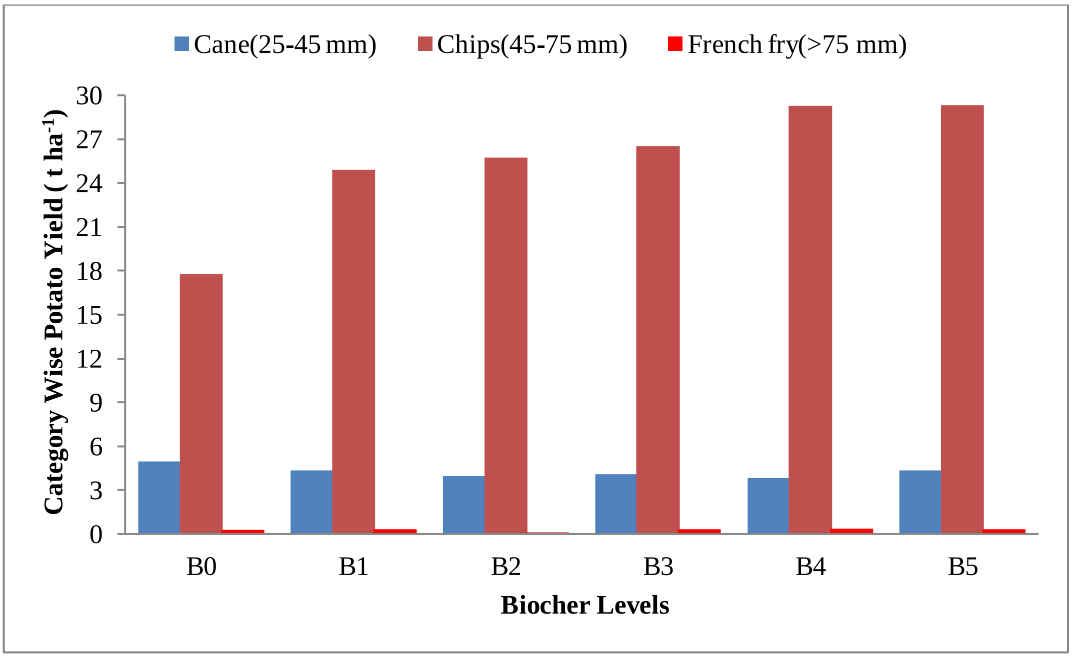
Up- Prilled urea, Us- Urea Super granules

Figure 21: Effect of urea forms on category wise potato yield (t ha^{-1}) {$LSD_{(0.05)}$=(NS, 1.2751 and NS at Cane(25-45 mm), Chips(45-75 mm) and French fry (>75 mm) potato}.

4.2.5.2 Effect of biochar

Biochar levels showed significant variation on category wise potato yield (t ha^{-1}) (Figure 22). From the experiment result revealed that, in case of cane potato (25-45mm), maximum potato yield (4.9733 t ha^{-1}) was observed from B_0 treatment, in case of Chips (45-75 mm) potato, maximum potato yield (29.331 t ha^{-1}) was observed from B_5 treatment which was statistically similar with B_4 treatment and in case of French fry (>75 mm) potato, maximum potato yield (0.3591 t ha^{-1}) was observed from B_4 treatment which was statistically similar with B_5 treatment. Whereas minimum cane potato (25-45mm) yield (3.8214 t ha^{-1}) was observed from B_4 treatment which was statistically similar with all other treatments except B_0 treatment, in case of Chips (45-75 mm) potato, minimum potato yield (17.795 t ha^{-1}) was observed from B_0

treatment and in case of French fry (>75 mm) potato, minimum potato yield (0.1053 t ha^{-1}) was observed from B_2 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 22: Effect of biochar levels on category wise potato yield (t ha^{-1}) {$LSD_{(0.05)}$= 0.5960, 2.4133 and 0.0292 at Cane(25-45 mm), Chips(45-75 mm) and French fry (>75 mm) potato}.

4.2.5.3 Combined effect of urea forms and biochar levels

Only onto Chips (45-75 mm) and French fry (>75 mm) potato, showed significant effect on category wise potato yield (t ha^{-1}) due to combined application of urea forms and biochar levels on the experimental field (Table 5). From the experiment, result revealed that in case of cane (25-45 mm) potato, the maximum yield (5.75 t ha^{-1}) was observed from U_sB_0 treatment combination, in case of Chips (45-75 mm) potato, the maximum yield (31.550 t ha^{-1}) was observed from U_sB_5 treatment combination which was statistically similar with U_sB_4, U_sB_3 and U_sB_2 treatment combination, and in case of French fry (>75 mm) potato, the maximum yield (0.4616 t ha^{-1}) was observed from U_pB_4 treatment combination which was statistically similar with U_sB_5, and U_pB_1 treatment combination. Whereas in case of cane (25-45 mm) potato, the minimum yield (3.3034t ha^{-1}) was observed from U_pB_4 treatment combination, in case of Chips (45-75 mm) potato, the minimum yield (17.666 t ha^{-1}) was observed from U_sB_0 treatment combination which was statistically similar with U_pB_0 treatment combination, and in case of French fry (>75 mm) potato, the minimum yield (0.0000 t ha^{-1}) was observed from U_sB_2 treatment combination which was statistically similar with U_sB_5, and U_pB_1 treatment combination.

Table 5: Combined effect of urea forms and biochar levels on category wise potato yield.

Treatment combinations	Yield of marketable potato (>20 g)	Category wise potato yield (t ha^{-1}) for		
		Cane (25-45 mm)	Chips (45-75 mm)	French fry (>75 mm)
U_pB_0	22.300 g	4.1967	17.923 e	0.1800 e
$U_p B_1$	27.327 ef	4.3020	22.581 d	0.4429 a
$U_p B_2$	26.533 ef	3.5956	22.726 d	0.2106 de
$U_p B_3$	28.466 de	3.8590	24.360 cd	0.2454 cd
$U_p B_4$	31.270 cd	3.3034	27.507 bc	0.4616 a
$U_p B_5$	31.537 cd	4.2176	27.111 bc	0.2095 de
$U_s B_0$	23.783 fg	5.7500	17.666 e	0.3700 b
$U_s B_1$	31.860 bcd	4.4300	27.213 bc	0.2146 de
$U_s B_2$	33.080 abc	4.2925	28.785 ab	0.0000 f
$U_s B_3$	33.373 abc	4.2891	28.685 ab	0.3981 b
$U_s B_4$	35.673 ab	4.3394	31.076 a	0.2565 c
$U_s B_5$	36.500 a	4.4915	31.550 a	0.4585 a
LSD $_{(0.05)}$	3.9238	NS	3.4129	0.0412
CV (%)	7.64	11.63	7.83	8.43

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

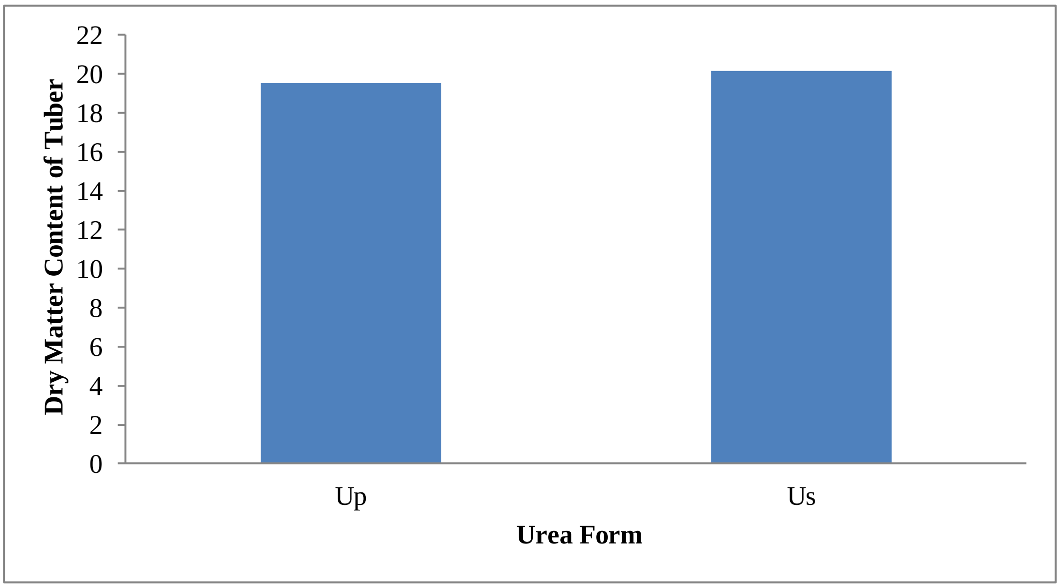
NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.3 Quality characters

4.3.1 Dry matter content of tuber (%)

4.3.1.1 Effect of urea forms

Urea forms showed significant effect on dry matter content of tuber (g) of potato (Figure 23). From the experiment result revealed that the maximum dry matter content of tuber (20.167 %) was observed in U_s treatment whereas the minimum dry matter content of tuber (19.533 %) was observed in U_p treatment. Application of biochar might have increased the tuber bulking than prilled urea which in turns increased the tuber yield categories for different purposes especially for french fry. More translocation of photosynthates from higher accumulation of nitrogen through urea super granule than prilled urea resulted higher partitioning of tuber dry matter.

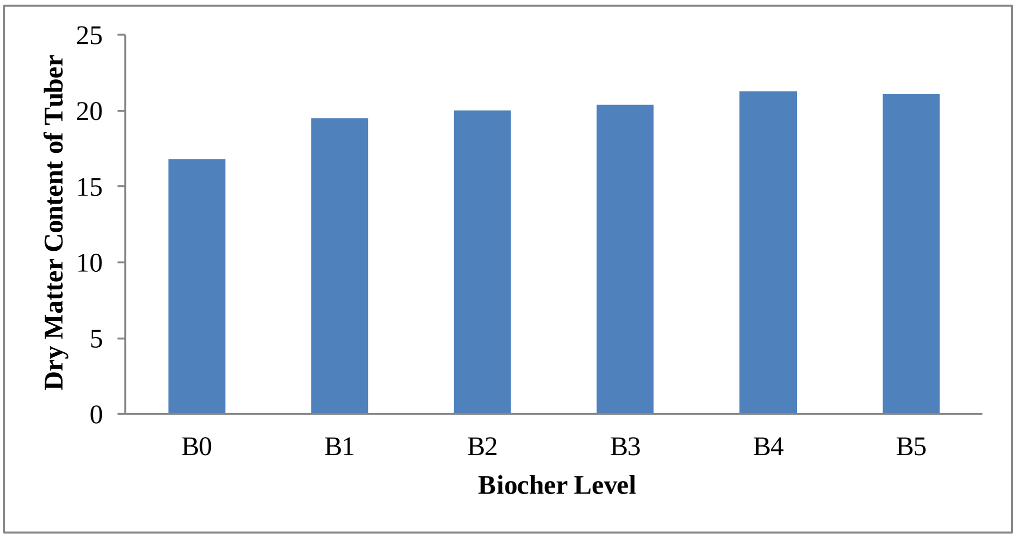


Up- Prilled urea, Us- Urea Super granules

Figure 23: Effect of urea forms on dry matter content of tuber (%) of potato ($LSD_{(0.05)}$= 0.0414).

4.3.1.2 Effect of biochar

Biochar levels showed significant variation on dry matter content of tuber (%) (Figure 24). From the experiment result showed that the maximum dry matter content of tuber of potato (21.30 %) was observed in B_4 treatment. Whereas the minimum dry matter content of tuber of potato (16.80 %) was observed in B_0 treatment. Applying biochar might have increased the tuber texture and total soluble solid which in turns increased the percent of dry matter content.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 24: Effect of biochar levels on dry matter content of tuber (%) of potato ($LSD_{(0.05)}$= 0.1467).

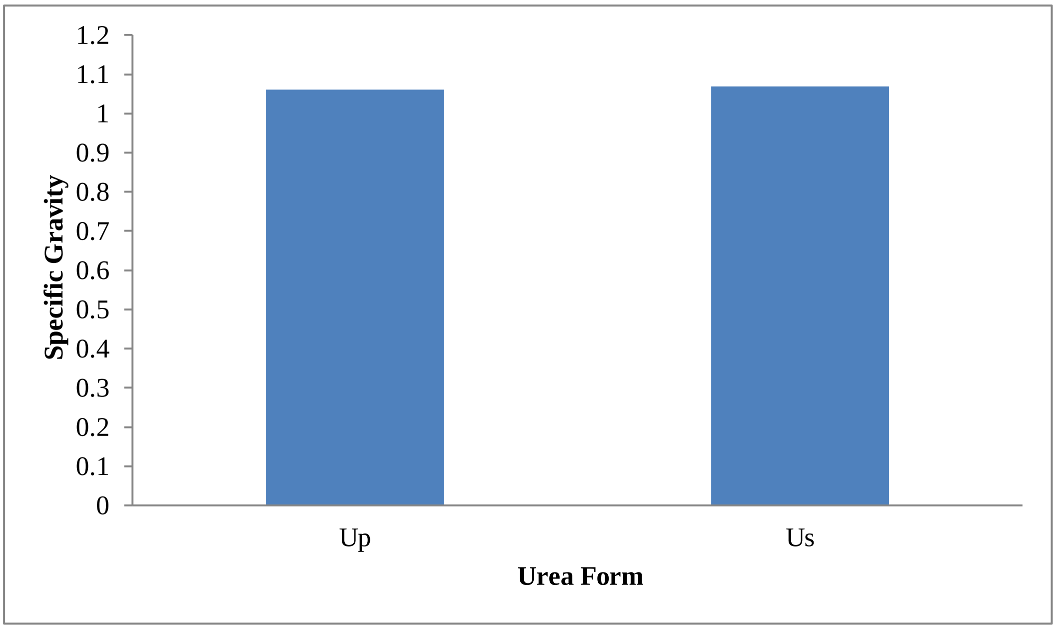
4.3.1.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect on dry matter content of tuber (%) of potato (Table 6). From the experiment result revealed that the maximum dry matter content of tuber of potato (21.80 %) was observed from U_sB_4 treatment combination which was statistically similar with U_sB_5 treatment combination. Some of other combination such as U_SB_2, U_SB_3 also meet the export criteria (>20% dry matter content).Whereas the minimum dry matter content of tuber of potato (16.700 %) was observed from U_pB_0 treatment combination.

4.3.2 Specific gravity (g cc^{-1})

4.3.2.1 Effect of urea forms

Urea forms showed significant effect on specific gravity of potato (Figure 25). From the experiment result revealed that the maximum specific gravity of potato (1.0695 g cc^{-1}) was observed in U_S treatment (Urea Super Granule) whereas the minimum specific gravity of potato (1.0602 g cc^{-1}) was observed in U_p treatment (Prilled Urea). Higher nitrogen accumulation from urea super granule increased the weight of individual tuber which might have given higher tuber yield per hectare and the higher tuber weight might have increased the specific gravity of tuber which is correlated to higher dry matter content of tuber.

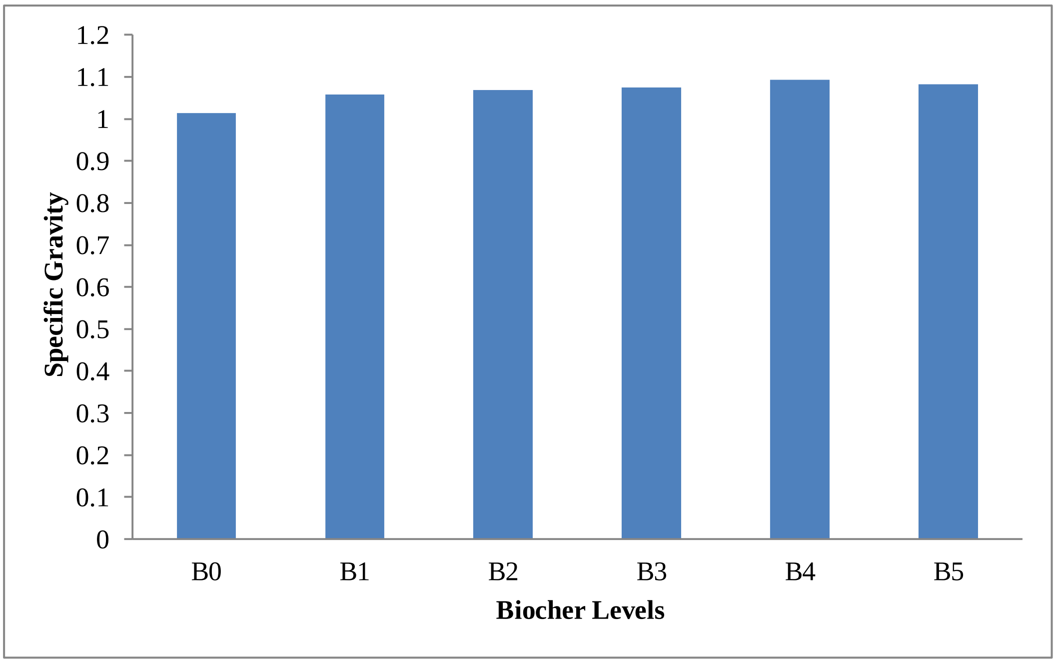


Up- Prilled urea, Us- Urea Super granules

Figure 25: Effect of urea forms on specific gravity (g cc^{-1}) potato (LSD $_{(0.05)}$ = 0.009).

4.3.2.2 Effect of biochar

Biochar levels showed significant variation on specific gravity of potato (Figure 26). From the experiment result showed that the maximum specific gravity of potato (1.0924 g cc^{-1}) was observed in B_4 treatment. Whereas the minimum specific gravity of potato (1.0139 g cc^{-1}) was observed in B_0 treatment. Application of biochar might have increased the tuber bulking than prilled urea which in turns increased the tuber specific gravity.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 26: Effect of biochar levels on specific gravity (g cc^{-1}) potato ($LSD_{(0.05)}$= 0.0074).

4.3.2.3 Combined effect of urea forms and biochar levels

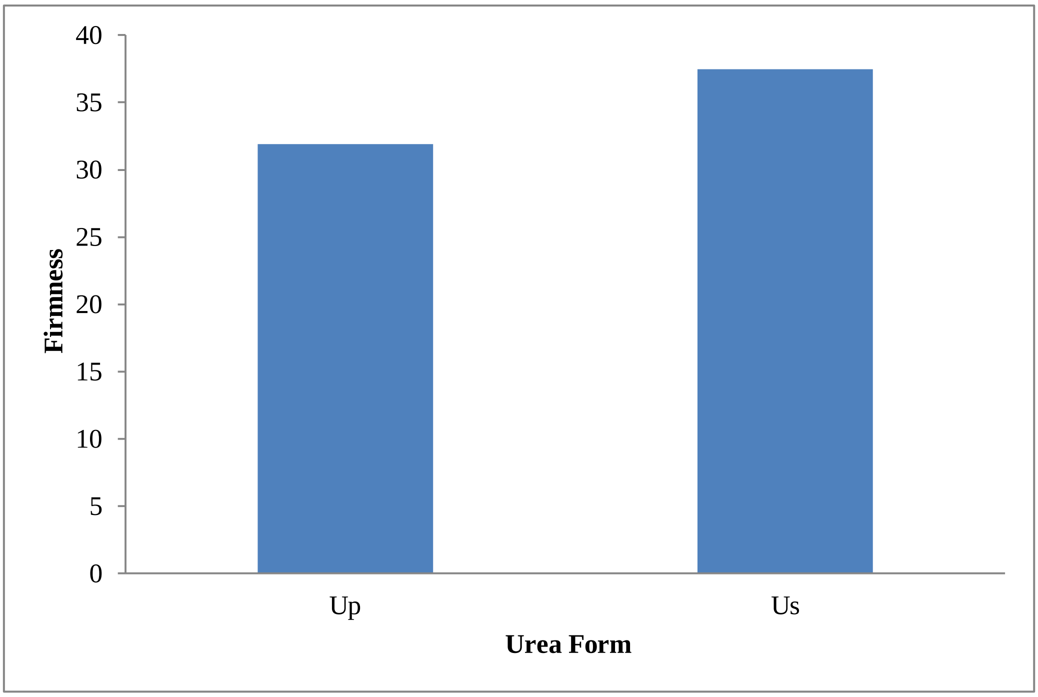
Combined effect of urea forms and biochar levels showed significant effect on specific gravity of potato (Table 6). From the experiment result revealed that the maximum specific gravity of potato (1.0980 g cc^{-1}) was observed from U_sB_4 treatment combination which was statistically similar with U_pB_5 whereas the minimum specific gravity of potato (1.0012 g cc^{-1}) was observed from U_pB_0 treatment combination.

4.3.3 Firmness (N)

Firm" means that the potato is compact, solid, not shriveled or flabby or pliable and unyielding to moderate pressure.

4.3.3.1 Effect of urea forms

Urea forms showed significant effect on firmness of potato (Figure 27). From the experiment result revealed that the maximum firmness of potato (37.463 N) was observed in U_s treatment whereas the minimum firmness (31.898 N) was observed in U_p treatment.

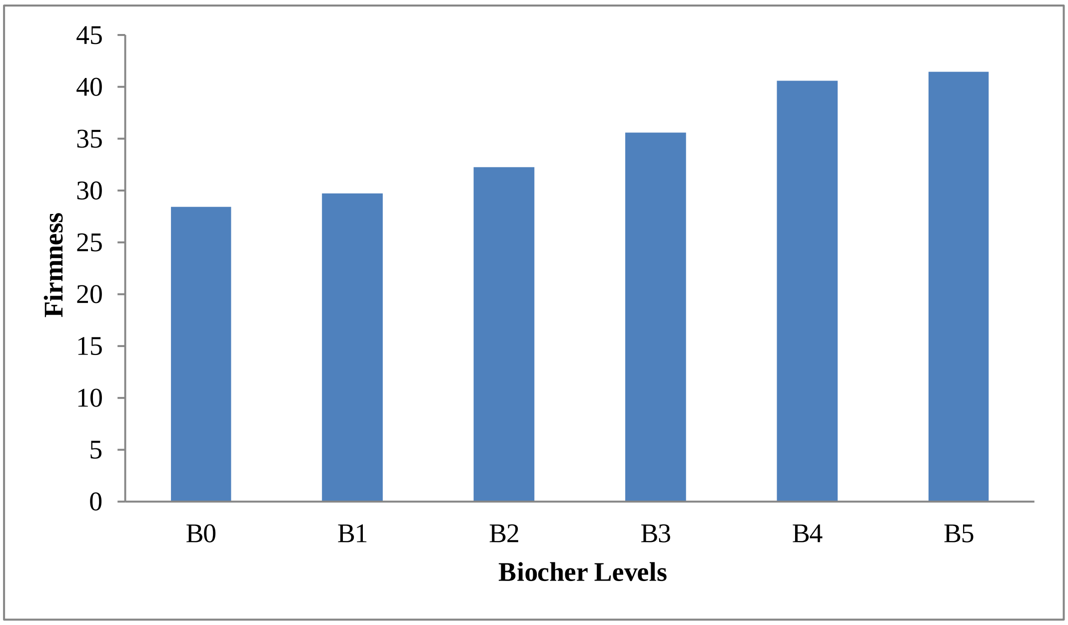


Up- Prilled urea, Us- Urea Super granules

Figure 27: Effect of urea forms on firmness (N) of potato (LSD $_{(0.05)}$= 0.8791).

4.3.3.2 Effect of biochar

Biochar levels showed significant variation on firmness of potato (Figure 28). From the experiment result showed that the maximum firmness of potato (41.440 N) was observed in B_5 treatment which was statistically similar with B_4 treatment. Whereas the minimum firmness of potato (28.452 N) was observed in B_0 treatment which was statistically similar with B_1 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 28: Effect of biochar levels on firmness (N) of potato (LSD $_{(0.05)}$ = 3.4611).

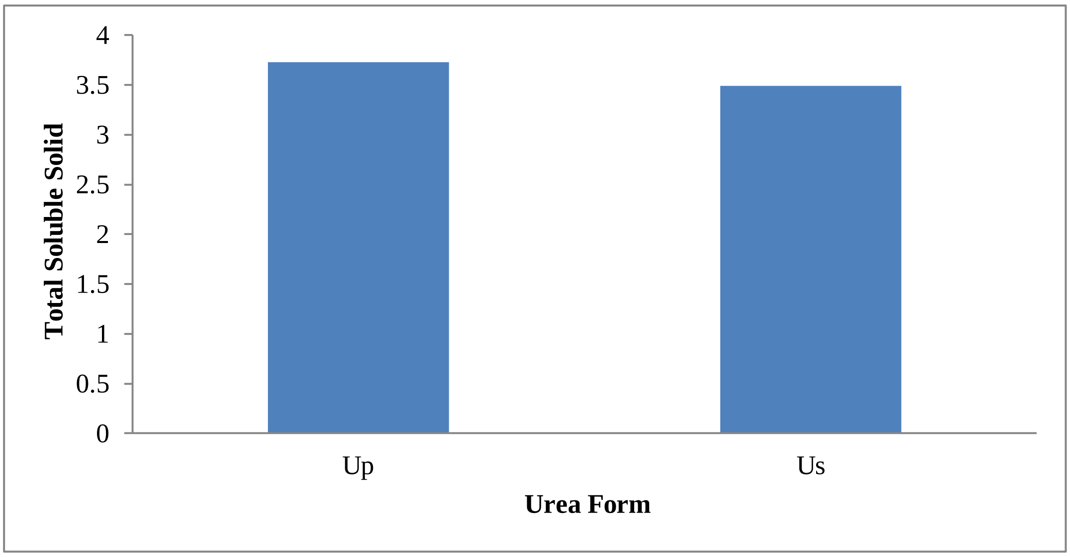
4.3.3.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on firmness of potato (Table 6). From the experiment result revealed that the maximum firmness of potato (45.367 N) was observed from U_sB_5 treatment combination. Whereas the minimum firmness of potato (26.480 N) was observed from U_pB_0 treatment combination.

4.3.4 Total soluble solid (^{0}Brix) (TSS)

4.3.4.1 Effect of urea forms

Urea forms showed significant effect on total soluble solid of potato. From the experiment result revealed that the maximum total soluble solid of potato (3.7293) was observed in U_p treatment (Prilled Urea) whereas the minimum total soluble solid of potato (3.4940) was observed in U_s treatment (Urea Super Granule).

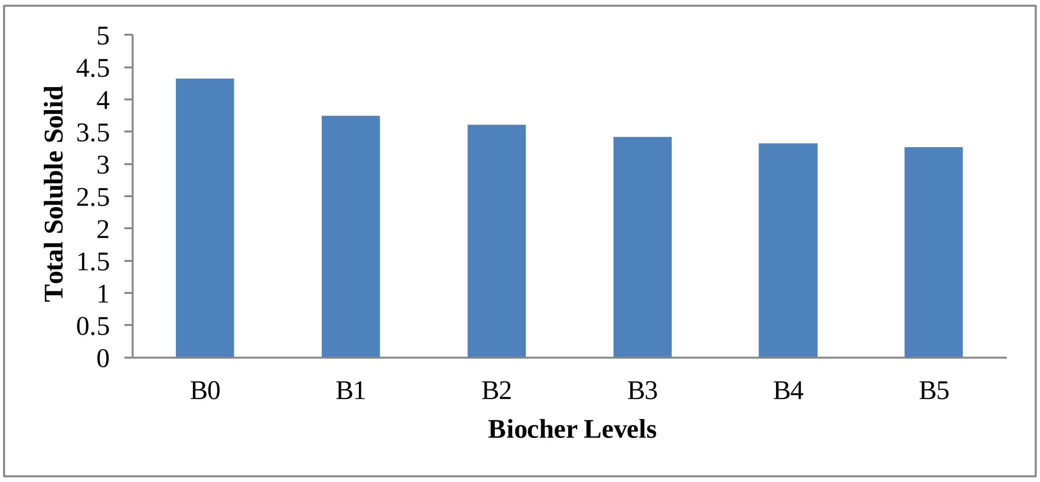


Up- Prilled urea, Us- Urea Super granules

Figure 29: Effect of urea forms on total soluble solid of potato ($LSD_{(0.05)}$= 0.1486).

4.3.4.2 Effect of biochar

Biochar levels showed significant variation on total soluble solid of potato (Figure 30). From the experiment result showed that the maximum total soluble solid of potato (4.3206) was observed in B_0 treatment. Whereas the minimum total soluble solid of potato (3.2604) was observed in B_5 treatment which was statistically similar with B_4 treatment followed by B_3 and B_3 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 30: Effect of biochar levels on total soluble solid of potato ($LSD_{(0.05)}$ = 0.4037).

4.3.4.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on total soluble solid of potato (Table 6). From the experiment result revealed that the maximum total soluble solid of potato (4.4667) was observed from U_pB_0 treatment combination. Whereas the minimum total soluble solid of potato (3.1332) was observed from U_sB_5 treatment combination. Higher nitrogen accumulation from urea super granule along with biochar might have increased the concentration of tuber starch which in turns might have increased the total soluble solid content of tuber.

Table 6: Combined effect of urea forms and biochar levels on specific gravity, total soluble solid, firmness and dry matter of potato.

Treatment	Dry matter (DM) (%)	Specific gravity (SG) (g cc^{-1})	Firmness (N)	Total soluble solid (^{0}Brix)
U_pB_0	16.700 h	1.0012 g	26.480	4.4667
U_pB_1	19.300 f	1.0533 e	28.040	3.8667
U_pB_2	19.700 e	1.0667 cd	29.743	3.7547
U_pB_3	20.100 d	1.0767 bc	31.527	3.5333
U_pB_4	20.600 b	1.0767 bc	37.513	3.3875
U_pB_5	20.800 b	1.0867 ab	38.083	3.3667
U_sB_0	16.900 g	1.0267 f	30.423	4.1745
U_sB_1	19.700 e	1.0633 de	31.373	3.6333
U_sB_2	20.300 c	1.0699 cd	34.770	3.4578
U_sB_3	20.700 b	1.0724 cd	39.667	3.2985
U_sB_4	21.800 a	1.0980 a	43.177	3.2667
U_sB_5	21.600 a	1.0867 b	45.367	3.1332
LSD $_{(0.05)}$	0.2074	0.0105	NS	NS
CV(%)	3.61	3.58	8.29	9.28

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

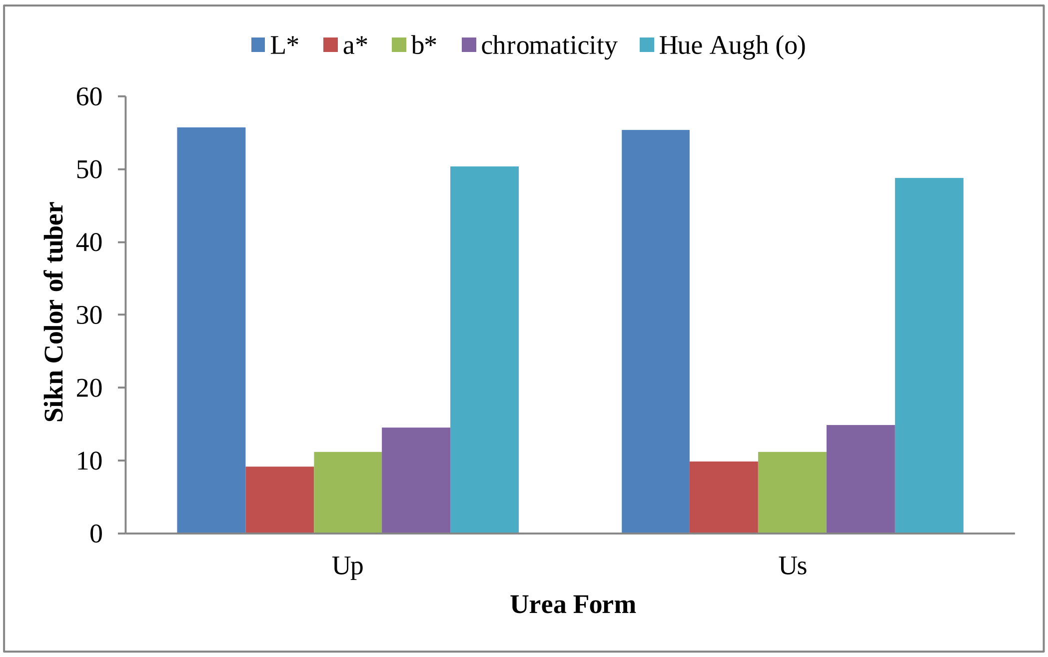
NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.3.5 Skin color of tuber

4.3.5.1 Effect of urea forms

Urea forms showed non significant effect on skin color of tuber {Lightness (L), Redness to greenness (a), black (b), chromaticity, and Hue Augh} of potato (Figure 31). From the experiment result revealed that the maximum lightness of potato

(55.729) was observed in U_p treatment, the maximum redness to greenness (9.8494) was observed in U_s treatment, the maximum blackness (11.197) was observed in U_p treatment, the maximum chromaticity (14.901) was observed in U_s treatment, and the maximum Hue Augh (50.411) was observed in U_p treatment. Whereas the minimum lightness (55.371) was observed in U_s treatment, the minimum redness to greenness (9.1933) was observed in U_p treatment, the minimum blackness (11.178) was observed in U_s treatment, the minimum chromaticity (14.547) was observed in U_p treatment, and the minimum Hue Augh (48.793) was observed in U_s treatment.



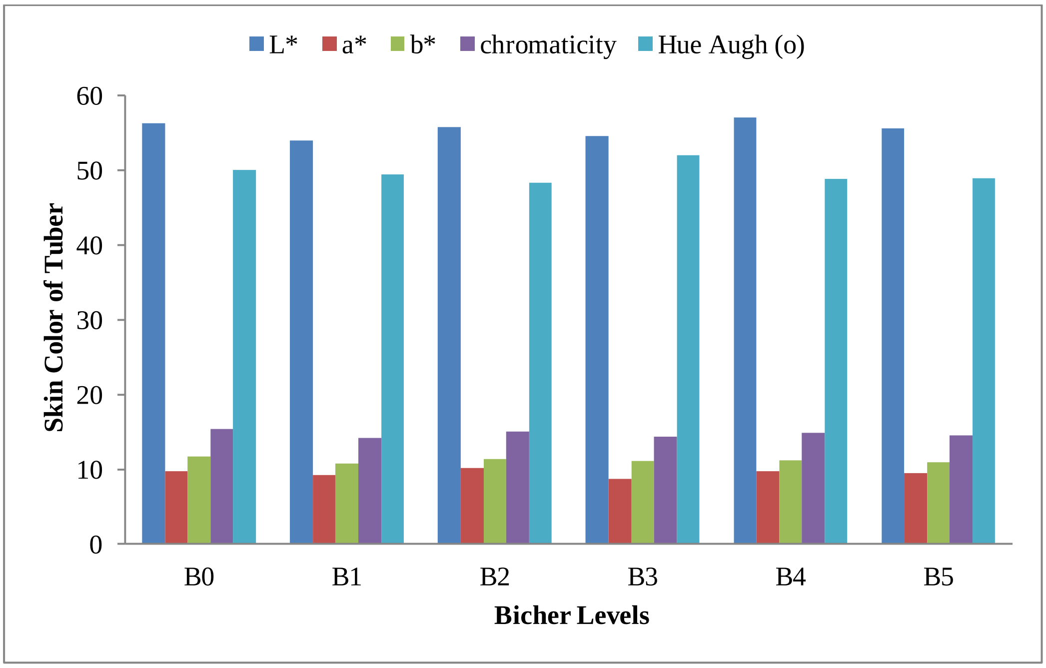
Up- Prilled urea, Us- Urea Super granules

Figure 31: Effect of urea forms on skin color of tuber (g) of potato ($LSD_{(0.05)}$= NS,NS, NS, NS, and NS at L*, a*, b*,chromaticity and Hue Augh).

4.3.5.2 Effect of biochar

Biochar levels showed non significant effect on skin color of tuber {Lightness (L), Redness to greenness (a), black (b), chromaticity, and Hue Augh} of potato (Figure 32). From the experiment result revealed that the maximum lightness (57.030) was observed in B_4 treatment, the maximum redness to greenness (10.215) was observed in B_2 treatment, the maximum blackness (11.713) was observed in B_0 treatment, the maximum chromaticity (15.363) was observed in B_0 treatment, and the maximum Hue Augh (51.970) was observed in B_3 treatment. Whereas the minimum lightness

(54.012) was observed in B_1 treatment, the minimum redness to greenness (8.698) was observed in B_3 treatment, the minimum blackness (10.780) was observed in B_1 treatment, the minimum chromaticity (14.225) was observed in B_1 treatment, and the minimum Hue Augh (48.352) was observed in B_2 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 32: Effect of biochar levels on skin color of tuber (g) of potato ($LSD_{(0.05)}$= NS,NS, NS, NS, and NS at L*, a*, b*,chromaticity and Hue Augh).

4.3.5.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on skin color of tuber {Lightness (L), Redness to greenness (a), black (b), chromaticity, and Hue Augh} of potato (Table 7). From the experiment result revealed that the maximum lightness (58.150) was observed in U_sB_4 treatment combination, the maximum redness to greenness (11.447) was observed in U_sB_2 treatment combination, the maximum blackness (12.037) was observed in U_pB_0 treatment combination, the maximum chromaticity (15.393) was observed in U_sB_0 treatment combination, and the maximum Hue Augh (52.797) was observed in U_pB_2 treatment combination. Whereas the minimum lightness (53.213) was observed in U_sB_3 treatment combination, the minimum redness to greenness (8.340) was observed in U_pB_1 treatment combination, the minimum blackness (10.130) was observed in U_pB_1

treatment combination, the minimum chromaticity (13.123) was observed in U_pB_1 treatment combination, and the minimum Hue Augh (43.907) was observed in U_s B_2 treatment combination.

Table 7: Combined effect of urea forms and biochar levels on skin color of potato.

Treatment	Skin color of potato				
	Lightness (L)	Redness to Greenness (a)	Black	chromaticity	Hue Augh (^{o})
U_pB_0	56.213	9.500	12.037	15.333	51.700
U_pB_1	53.403	8.340	10.130	13.123	50.493
U_pB_2	56.000	8.983	11.743	14.797	52.797
U_pB_3	56.007	8.447	11.257	14.293	52.070
U_pB_4	55.910	9.937	10.853	14.760	47.160
U_pB_5	56.843	9.953	11.160	14.973	48.243
U_sB_0	56.357	10.030	11.390	15.393	48.450
U_sB_1	54.620	10.170	11.430	15.327	48.427
U_sB_2	55.460	11.447	10.983	15.227	43.907
U_sB_3	53.213	8.950	10.973	14.443	51.870
U_sB_4	58.150	9.483	11.523	14.957	50.557
U_sB_5	54.427	9.017	10.767	14.057	49.547
LSD $_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	3.58	12.01	11.92	9.87	8.90

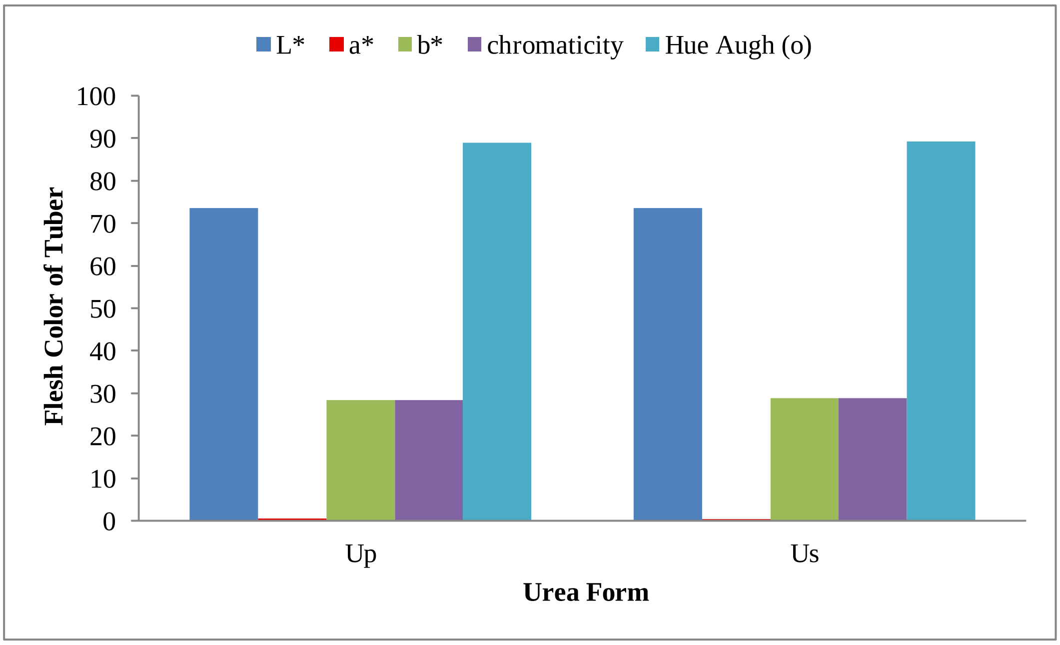
In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.3.6 Flesh color of tuber

4.3.6.1 Effect of urea forms

Urea forms showed non significant effect on flesh color of tuber {Lightness (L), Redness to greenness (a), black (b), chromaticity, and Hue Augh} of potato (Figure 33). From the experiment result revealed that the maximum lightness (73.641) was observed in U_s treatment, the maximum redness to greenness (0.5578) was observed in U_p treatment, the maximum blackness (28.799), chromaticity (28.799), and Hue Augh (89.170) were observed in U_s treatment. Whereas the minimum lightness (73.609) was observed in U_p treatment, the minimum redness to greenness (0.4211) was observed in U_s treatment, the minimum blackness (28.438), chromaticity (28.438), and Hue Augh (88.890) were observed in U_p treatment.



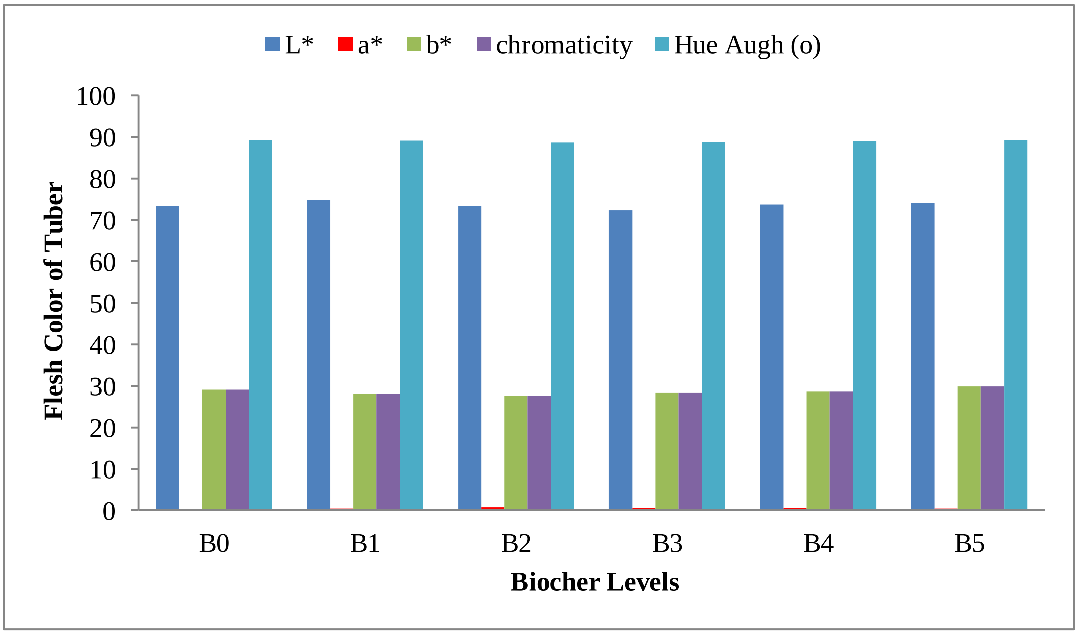
Up- Prilled urea, Us- Urea Super granules

Figure 33: Effect of urea forms on flesh color of tuber (g) of potato ($LSD_{(0.05)}$= NS,NS, NS, NS, and NS at L*, a*, b*,chromaticity and Hue Augh).

4.3.6.2 Effect of biochar

Biochar levels showed showed significant effect on flesh color of tuber only at {Lightness (L), and Hue Augh} (Figure 34). From the experiment result revealed that the maximum lightness (74.857) was observed in B_1 treatment which was statistically similar with B_4 treatment followed by B_5 treatment, the maximum redness to greenness (0.6750) was observed in B_2 treatment, the maximum blackness (29.907) was observed in B_5 treatment, the maximum chromaticity (29.902) was observed in B_5 treatment, and the maximum Hue Augh (89.305) was observed in B_0 treatment which was statistically similar with B_5 treatment followed by B_1 and B_2 treatment. Whereas the minimum lightness (72.383) was observed in B_3 treatment which was statistically similar with B_2 treatment followed by B_0 treatment, the minimum redness to greenness (0.3583) was observed in B_0 treatment, the minimum blackness (27.637) was observed in B_2 treatment, the minimum chromaticity (27.647) was observed in B_2

treatment, and the minimum Hue Augh (88.635) was observed in B_2 treatment which was statistically similar with B_3 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 34: Effect of biochar levels on flesh color of tuber (g) of potato ($LSD_{(0.05)}$= 1.3248,NS, NS, NS, and 0.4525 at L*, a*, b*,chromaticity and Hue Augh).

4.3.6.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant effect on flesh color of tuber{Lightness (L), Redness to greenness (a), black (b), chromaticity, and Hue Augh} of potato (Table 8). From the experiment result revealed that the maximum lightness (74.597) was observed in U_pB_1 treatment combination, the maximum redness to greenness (0.6800) was observed in U_sB_2 treatment combination, the maximum blackness (30.650) and chromaticity (30.650) were observed in U_pB_5 treatment combination, and the maximum Hue Augh (89.627) was observed in U_sB_5 treatment combination. Whereas the minimum lightness (71.877) was observed in U_sB_3 treatment combination, the minimum redness to greenness (0.3333) was observed in U_sB_0 treatment combination, and the minimum blackness (26.917), chromaticity (26.927), and Hue Augh (88.590) were observed in U_pB_2 treatment combination.

Table 8: Combined effect of urea forms and biochar levels on flesh color of potato.

Treatment	Flesh color of potato				
	Lightness (L)	Redness to Greenness (a)	Black	chromaticity	Hue Augh (^{o})
U_pB_0	73.300	0.3833	28.947	28.817	89.247
U_pB_1	74.597	0.4700	27.667	27.663	89.063
U_pB_2	73.567	0.6700	26.917	26.927	88.590
U_pB_3	72.890	0.6633	28.280	28.290	88.667
U_pB_4	73.307	0.5800	28.273	28.280	88.823
U_pB_5	73.993	0.5800	30.650	30.650	88.950
U_sB_0	73.640	0.3333	29.293	29.297	89.363
U_sB_1	75.117	0.3267	28.403	28.407	89.343
U_sB_2	73.220	0.6800	28.357	28.367	88.680
U_sB_3	71.877	0.5000	28.397	28.403	88.980
U_sB_4	73.983	0.4967	29.180	29.167	89.027
U_sB_5	74.010	0.1900	29.163	29.153	89.627
LSD $_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	1.49	39.05	5.86	5.85	0.42

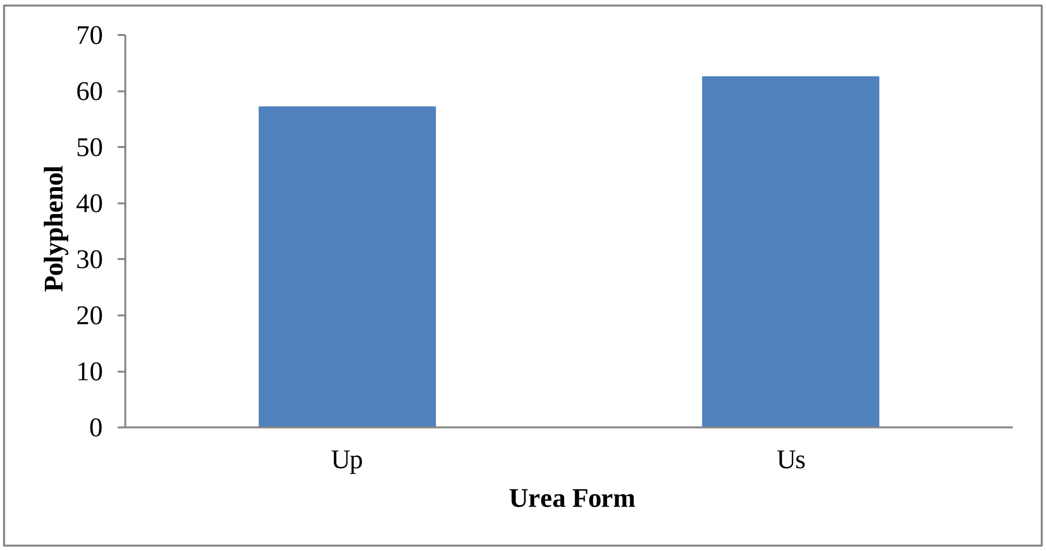
In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

4.3.7 Polyphenol (GA mg 100 g^{-1} FW)

4.3.7.1 Effect of urea forms

Urea forms showed significant effect on Polyphenol (GA mg 100 g^{-1} FW) of potato (Figure 35). From the experiment result revealed that the maximum Polyphenol (62.652) was observed in U_s treatment whereas the minimum Polyphenol (57.312) was observed in U_p treatment.

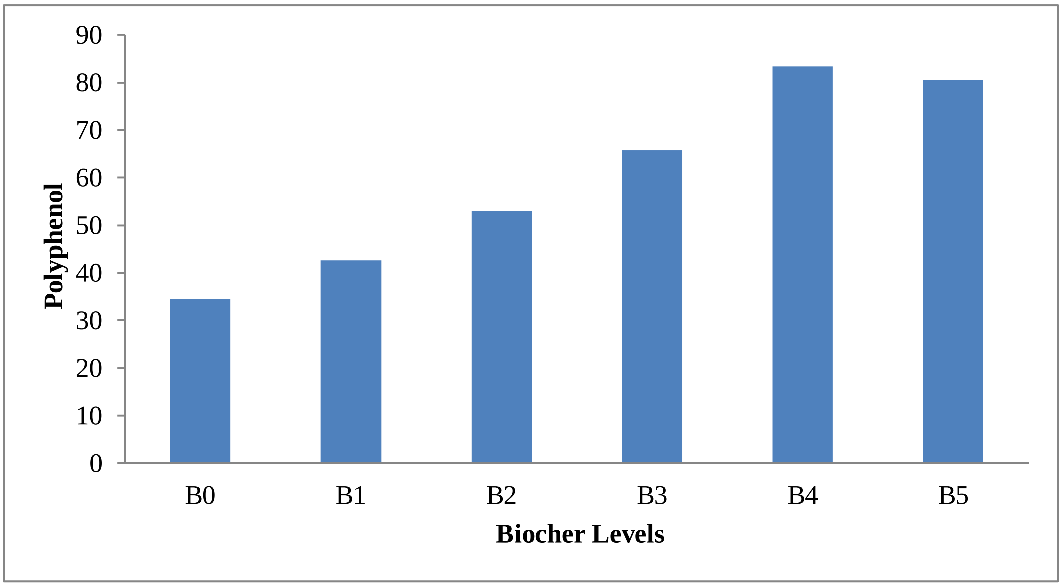


Up- Prilled urea, Us- Urea Super granules

Figure 35: Effect of urea forms on polyphenol (GA mg 100 g^{-1} FW) content of potato (LSD $_{(0.05)}$ = 0.6136).

4.3.7.2 Effect of biochar

Biochar levels showed significant variation on Polyphenol (GA mg 100 g^{-1} FW) of potato (Figure 36). From the experiment result showed that the maximum Polyphenol (GA mg 100 g^{-1} FW) of potato (83.323) was observed in B_4 treatment. Whereas the minimum Polyphenol of potato (34.531) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 36: Effect of biochar levels on polyphenol content of potato (LSD $_{(0.05)}$ = 3.98).

4.3.7.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect on Polyphenol (GA mg 100 g^{-1} FW) of potato (Table 9). From the experiment result revealed that the maximum Polyphenol of potato (87.523) was observed from U_sB_4 treatment combination. Whereas the minimum Polyphenol of potato (33.864) was observed from U_pB_0 treatment combination.

4.3.8 Starch (%)

4.3.8.1 Effect of urea forms

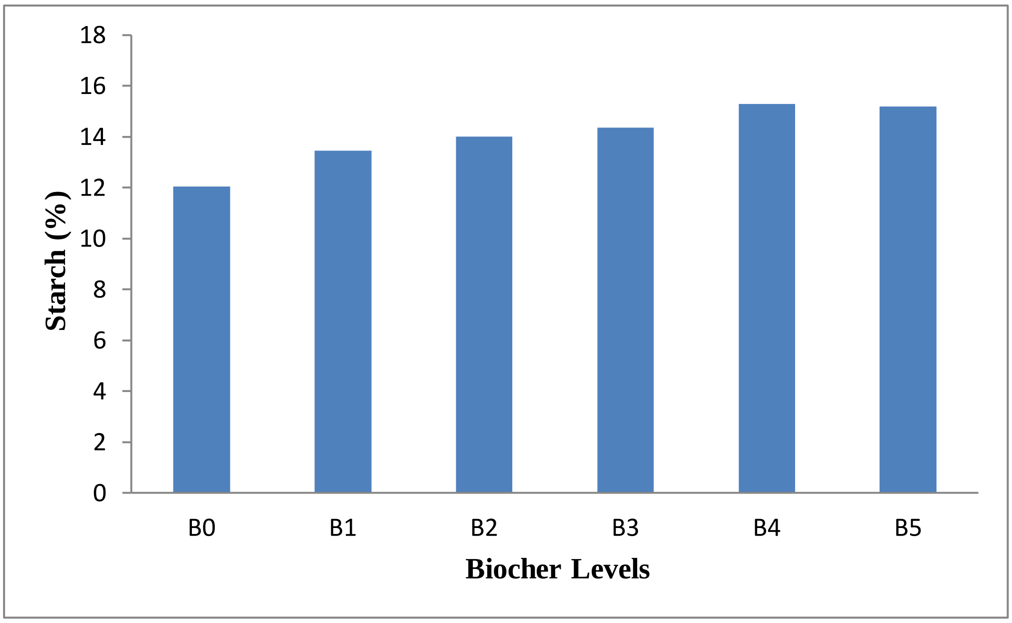
Urea forms showed significant effect on starch (%) of potato (Figure 37). From the experiment result revealed that the maximum starch (14.633%) was observed in U_s treatment whereas the minimum starch (13.483 %) was observed in U_p treatment.

Up- Prilled urea, Us- Urea Super granules

Figure 37: Effect of urea forms on starch (%) of potato ($LSD_{(0.05)}$= 1.02).

4.3.8.2 Effect of biochar

Biochar levels showed significant variation on starch (%) of potato (Figure 38). From the experiment result showed that the maximum starch of potato (15.300 %) was observed in B_4 treatment which was statistically similar with B_5 treatment. Whereas the minimum starch of potato (12.050 %) was observed in B_0 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 38: Effect of biochar levels on starch (%) of potato ($LSD_{(0.05)}$= 2.90).

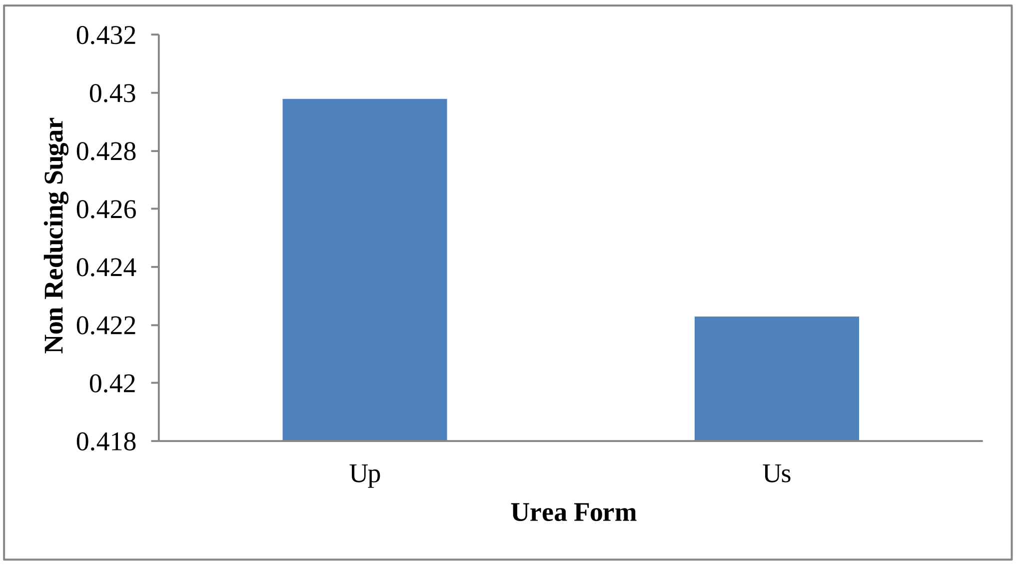
4.3.8.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant effect starch (%) of potato (Table 9). From the experiment result revealed that the maximum starch of potato (15.900 %) was observed from U_sB_4 treatment combination which was statistically similar with U_sB_5 treatment combination. Whereas the minimum starch of potato (10.400 %) was observed from U_pB_0 treatment combination.

4.3.9 Non Reducing Sugar (mg g^{-1}FW)

4.3.9.1 Effect of urea forms

Urea forms showed non significant effect on non reducing sugar (mg g^{-1} FW) of potato (Figure 39). From the experiment result revealed that the maximum non reducing sugar (0.4298 mg g^{-1} FW) was observed in U_p treatment whereas the minimum non reducing sugar (0.4223 mg g^{-1} FW) was observed in U_s treatment.

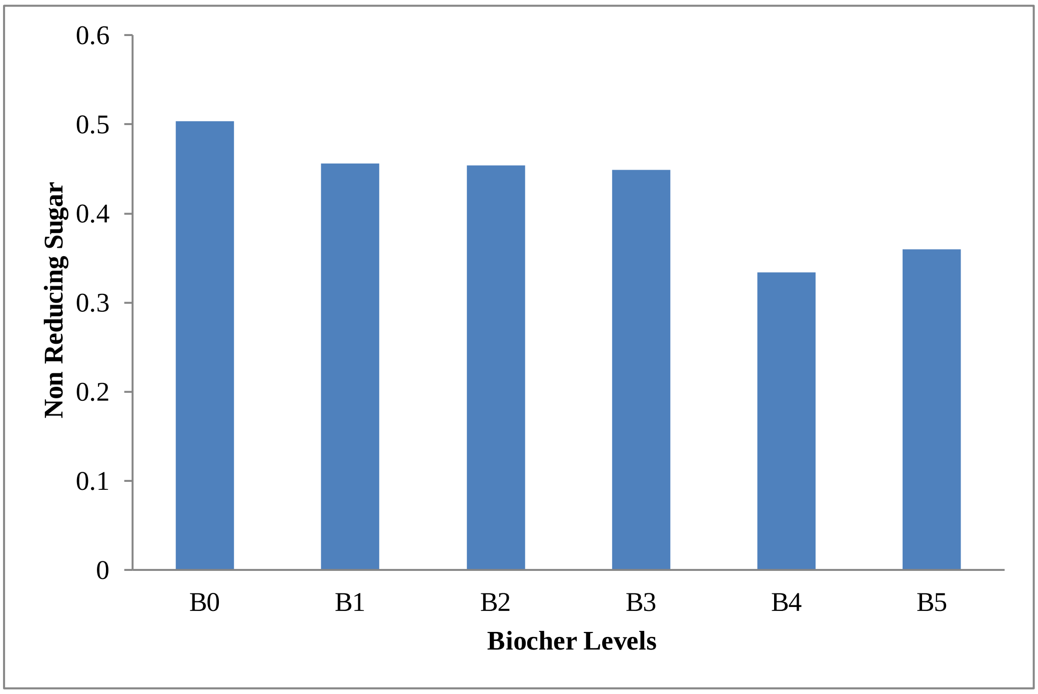


Up- Prilled urea, Us- Urea Super granules

Figure 39: Effect of urea forms on non reducing sugar (mg g^{-1}FW) of potato (LSD $_{(0.05)}$ = NS).

4.3.9.2 Effect of biochar

Biochar levels showed significant variation on non reducing sugar (mg g^{-1} FW) of potato (Figure 40). From the experiment result showed that the maximum non reducing sugar of potato (0.5034 mg g^{-1} FW) was observed in B_0 treatment. Whereas the minimum non reducing sugar of potato (0.3342 mg g^{-1} FW) was observed in B_4 treatment which was statistically similar with B_5 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 40: Effect of biochar levels on non reducing sugar (mg g^{-1}FW) of potato ($LSD_{(0.05)}$= 6.52).

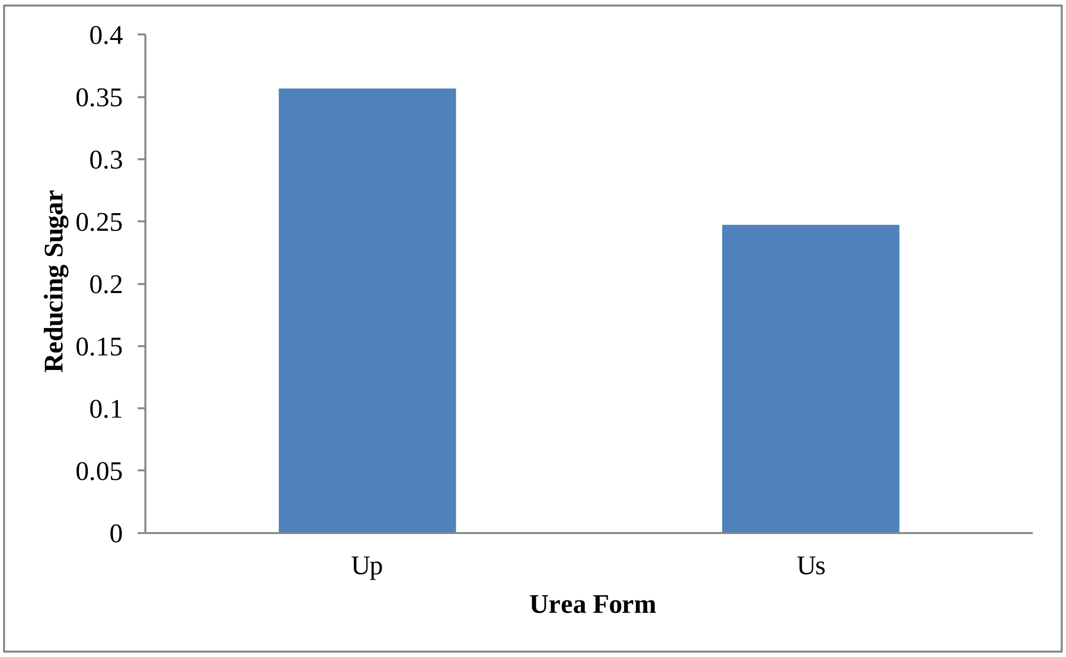
4.3.9.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant variation on non reducing sugar (mg g^{-1} FW) of potato (Table 9). From the experiment result revealed that the maximum non reducing sugar of potato (0.5067 mg g^{-1} FW) was observed from U_pB_0 treatment combination. Whereas the minimum non reducing sugar of potato (0.3109 mg g^{-1} FW) was observed from U_sB_4 treatment combination.

4.3.10 Reducing Sugar (mg g^{-1}FW)

4.3.10.1 Effect of urea forms

Urea forms showed significant effect on reducing sugar (mg g^{-1} FW) of potato (Figure 41). From the experiment result revealed that the maximum reducing sugar (0.3568 mg g^{-1} FW) was observed in U_p treatment whereas the minimum reducing sugar (0.2472 mg g^{-1} FW) was observed in U_s treatment.

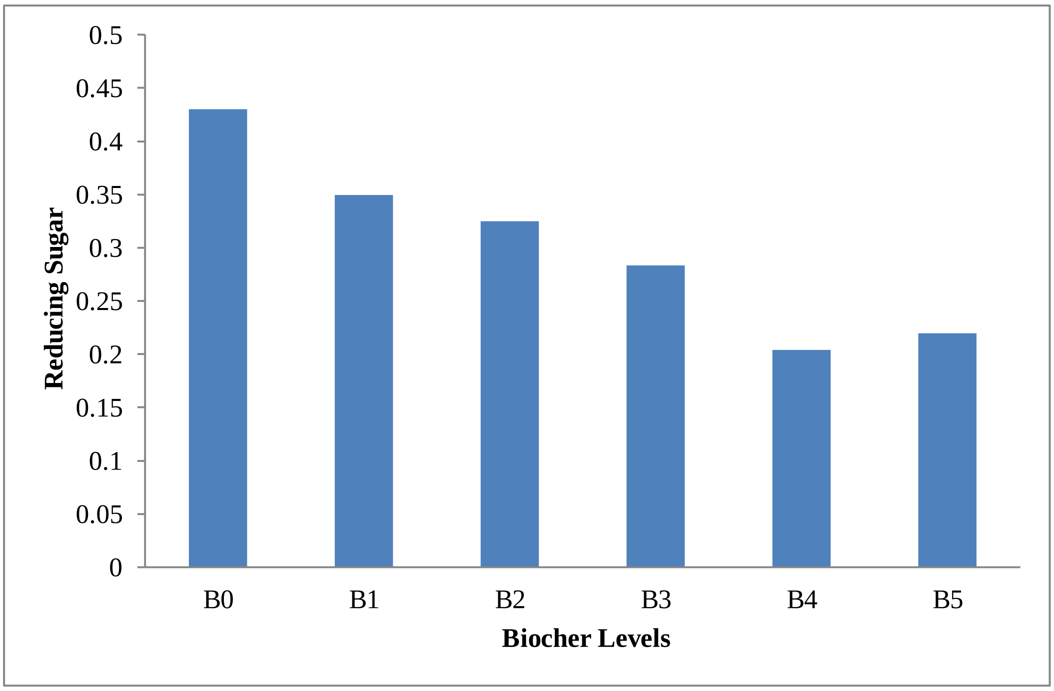


Up- Prilled urea, Us- Urea Super granules

Figure 41: Effect of urea forms on reducing sugar (mg g^{-1}FW) of potato (LSD $_{(0.05)}$ = 3.70).

4.3.10.2 Effect of biochar

Biochar levels showed significant variation on reducing sugar (mg g^{-1} FW) of potato (Figure 42). From the experiment result showed that the maximum reducing sugar of potato (0.4304 mg g^{-1} FW) was observed in B_0 treatment. Whereas the minimum reducing sugar of potato (0.2042 mg g^{-1} FW) was observed in B_4 treatment which was statistically similar with B_5 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 42: Effect of biochar levels on reducing sugar (mg g^{-1}FW) of potato (LSD$_{(0.05)}$= 6.11).

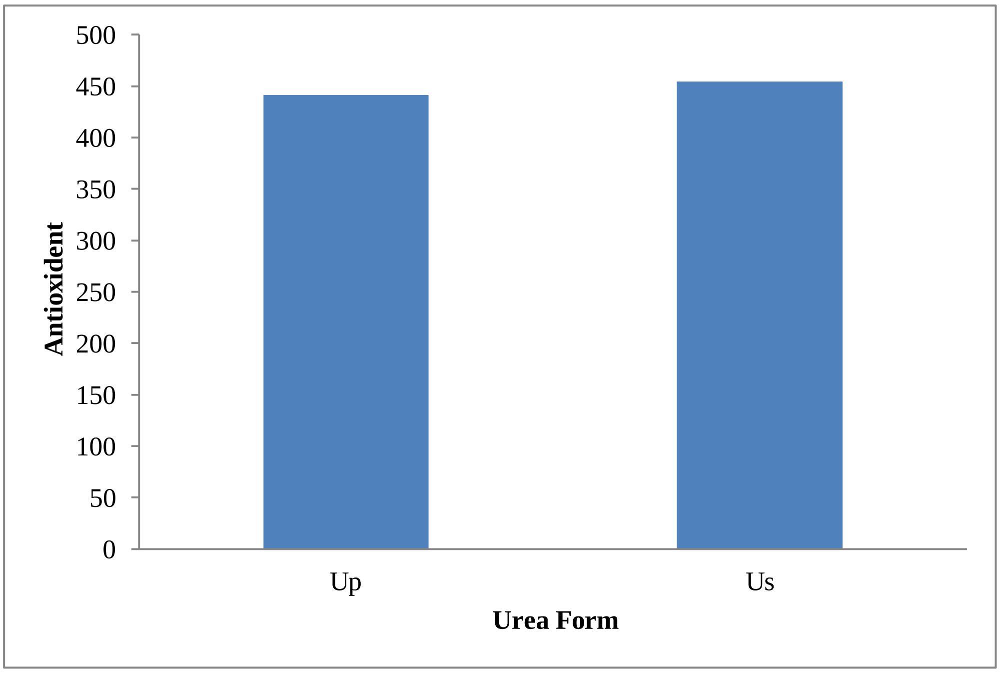
4.3.10.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed significant variation on non reducing sugar (mg g^{-1} FW) of potato (Table 9). From the experiment result revealed that the maximum reducing sugar of potato (0.5321 mg g^{-1} FW) was observed from U_pB_0 treatment combination. Whereas the minimum reducing sugar of potato (0.1452 mg g^{-1} FW) was observed from U_sB_4 treatment combination which was statistically similar with U_sB_5 treatment combination.

4.3.11 Antioxidant (Trolox µg 100 g^{-1} FW)

4.3.11.1 Effect of urea forms

Urea forms showed significant effect on antioxidant (Trolox µg 100 g^{-1} FW) of potato (Figure 43). From the experiment result revealed that the maximum antioxidant (454.56 Trolox µg 100 g^{-1} FW) was observed in U_s treatment whereas the minimum antioxidant (441.11 Trolox µg 100 g^{-1} FW) was observed in U_p treatment.

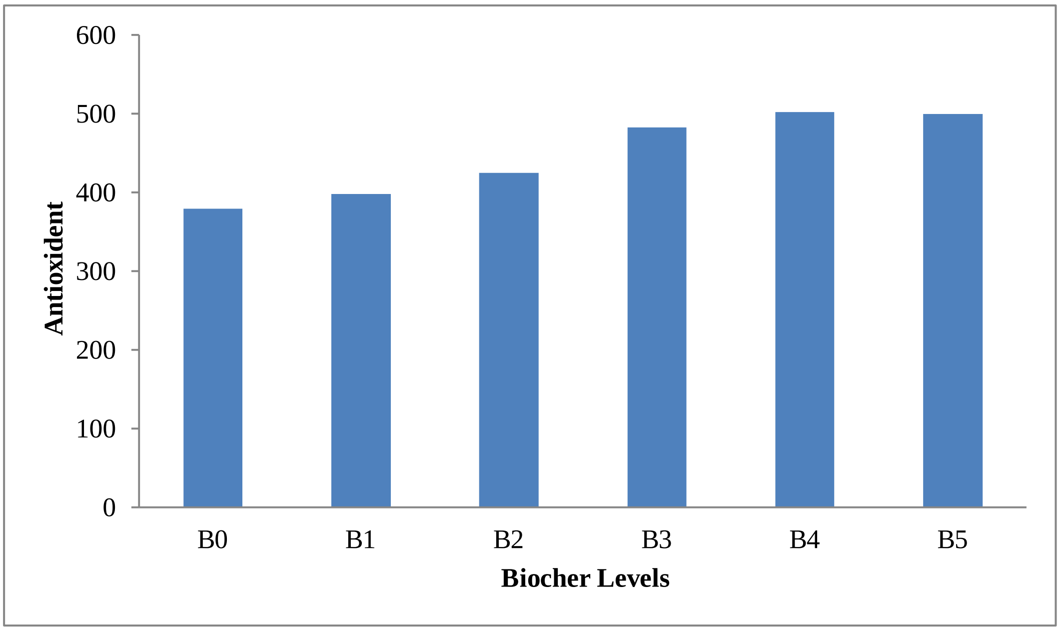


Up- Prilled urea, Us- Urea Super granules

Figure 43: Effect of urea forms on antioxidant (Trolox µg 100 g^{-1} FW) of potato (LSD$_{(0.05)}$= 10.980).

4.3.11.2 Effect of biochar

Biochar levels showed significant variation on antioxidant (Trolox µg 100 g^{-1} FW) of potato (Figure 44). From the experiment result showed that the maximum antioxidant of potato (502.01 Trolox µg 100 g^{-1} FW) was observed in B_4 treatment which was statistically similar with B_5 treatment followed by B_3 treatment. Whereas the minimum antioxidant of potato (379.39 µg 100 g^{-1} FW) was observed in B_0 treatment which was statistically similar with B_1 treatment.



B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

Figure 44: Effect of biochar levels on antioxidant (Trolox µg 100 g^{-1} FW) of potato (LSD $_{(0.05)}$ = 7.11).

4.3.11.3 Combined effect of urea forms and biochar levels

Combined effect of urea forms and biochar levels showed non significant variation antioxidant (Trolox µg 100 g^{-1} FW) of potato (Table 9). From the experiment result revealed that the maximum antioxidant of potato (509.23 µg 100 g^{-1} FW) was observed from U_sB_4 treatment combination. Whereas the minimum antioxidant of potato (366.47µg 100 g^{-1} FW) was observed from U_pB_0 treatment combination.

Table 9: Combined effect of urea forms and biochar levels on some biochemical parameters of potato.

Treatment	Polyphenol (GA mg 100 g^{-1} FW)	Starch (%)	Non Reducing Sugar (mg g^{-1}FW)	Reducing Sugar (mg g^{-1}FW)	Antioxident (Trolox µ Mol 100 g^{-1} FW)
U_pB_0	33.864 k	10.400 g	0.5067	0.5321 a	366.47
$U_p B_1$	42.494 i	13.400 f	0.4500	0.3921 b	395.97
$U_p B_2$	48.631 h	13.700 e	0.4515	0.3616 b	417.89
$U_p B_3$	62.437 f	14.100 d	0.4476	0.3001 cd	480.21
$U_p B_4$	77.322 d	14.600 b	0.3655	0.2915 de	491.32
$U_p B_5$	79.123 c	14.700 b	0.3575	0.2632 e	494.79
$U_s B_0$	35.198 j	13.700 e	0.5001	0.3287 c	392.31
$U_s B_1$	42.720 i	13.500 f	0.4619	0.3065 cd	399.74
$U_s B_2$	57.369 g	14.300 c	0.4568	0.2877 de	432.87
$U_s B_3$	69.188 e	14.600 b	0.4501	0.2673 e	485.55
$U_s B_4$	87.523 a	15.900 a	0.3109	0.1452 f	509.23
$U_s B_5$	83.916 b	15.800 a	0.3541	0.1480 f	507.67
$LSD_{(0.05)}$	1.0049	0.1675	NS	0.0314	NS
CV (%)	3.98	2.90	6.52	6.11	7.11

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly.

NS= Non significant, U_p- Prilled urea, U_s- Urea Super granules,
B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during November 2019 to March 2020. To investigate the influence of urea forms and biochar levels on the yield and processing quality of potato. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors split plot design. Factor A: Urea forms (2); 1. Prilled Urea (Up), 2.Urea Super Granule (US), and Factor B: Biochar levels (6); B_0- Control, B_1- 2 t ha^{-1}, B_2- 4 t ha^{-1}, B_3- 6 t ha^{-1}, B_4-8 t ha^{-1}, B_5- 10 t ha^{-1}. The total numbers of unit plots were 36. The size of unit plot was 5.00 m^2 (2.5m×2m). Urea, triple super phosphate (TSP), zinc oxide and boric acid were used as sources of nitrogen, phosphorus, potassium, gypsum, zinc, boron and cowdung respectively. The doses of fertilizers were 350, 220, 250, 120, 10, 8 and 10000 kg ha^{-1} for urea, TSP, MP, Gypsum, ZnSO4, boric acid and cowdung respectively. Cowdung was applied 10 days before final land preparation. Total amount of TSP, ZnO, boric acid and half of urea was applied at basal doses during final land preparation. The remaining 50% prilled urea was side dressed in two equal splits at 25 and 45 days after planting (DAP) during first and second earthing up and the urea super granule was applied per plant in two split. Once during the land preparation and another split were applied at 45 DAP. Different dose of biochar were applied as per treatment advised. Data on yield and quality characters of potato were recorded to find out the suitable urea forms and optimum biochar levels for the quality yield of potato.

Result revealed that different growth, yield and quality characters of potato were significantly influenced by urea forms. From the experiment result showed that the maximum days to 50 % emergence of potato (16.989) was observed in Prilled Urea (U_p), maximum plant height of potato (46.050, 55.489 and 65.711 cm at 30, 55 and 80 DAP), number of leaves of potato (43.695, 58.544 and 63.826 at 30, 55 and 80 DAP), plant vigor at 55 DAP (9.3989), were observed in U_S treatment (Urea Super Granule), maximum number of stem hill^{-1} at 80 DAP (4.3225) was observed in U_p treatment, the maximum days to crop maturity of potato (required 104.0 days), tuber hill^{-1} of potato (8.7921), average tuber weight of potato (38.746 g), tuber yield of potato (34.084 t ha^{-1}), yield of marketable potato (32.378 t ha^{-1}), category wise potato yield, {Cane(25-45 mm), Chips(45-75 mm), and French fry (>75 mm) onto 4.5987, 27.496 and 0.2829 t ha^{-1} }, specific gravity of potato (1.0695 g cc^{-1}) were observed in U_S treatment (Urea Super Granule), maximum total soluble solid of potato (3.7293) was observed in U_p treatment (Prilled Urea), maximum firmness of potato (37.463 N), dry matter content of tuber (20.167 %) were observed in U_s treatment. In case of skin color maximum lightness of potato (55.729) was observed in U_p treatment, maximum redness to greenness of potato (9.8494) was observed in U_s treatment, the maximum blackness of potato (11.197) was observed in U_p treatment, the maximum chromaticity of potato (14.901) was observed in U_s treatment and the maximum Hue Augh of potato (50.411) was observed in U_p treatment. In case of flesh color the maximum lightness (73.641) was observed in U_s treatment, the maximum redness to greenness (0.5578) was observed in U_p treatment, the maximum blackness (28.799), chromaticity (28.799) and Hue Augh (89.170) were observed in U_s treatment. Maximum polyphenol (GA mg 100 g^{-1} FW) (62.652), starch (14.633%) were observed in U_s treatment, maximum non reducing sugar (0.4298 mg g^{-1} FW), reducing sugar (0.3568 mg g^{-1} FW) were observed in U_p treatment and maximum antioxidant (454.56 Trolox µg 100 g^{-1} FW) was observed in $U_{s.}$ Whereas minimum days to 50 % emergence of potato (15.906) was observed in Urea Super Granule (U_S), minimum plant height of potato (41.717, 49.589 and 62.695 cm at 30, 55 and 80 DAP) number of leaves of potato (40.062 , 53.498 and 59.60 at 30, 55 and 80 DAP), plant vigor at 55 DAP (8.0272), were observed in U_p treatment (Prilled Urea), minimum number of stem $hill^{-1}$ at 80 DAP (4.2223) was observed in U_s treatment, minimum days to crop maturity of potato (required 91.83 days), tuber $hill^{-1}$ of potato (8.2713), average tuber weight of potato (33.743 g), tuber yield of potato (29.199 t ha^{-1}), yield of marketable potato (27.906 t ha^{-1}), category wise potato yield, (Cane(25-45 mm), Chips(45-75 mm), and French fry (>75 mm) onto 3.9124, 23.702 and 0.2917 t ha^{-1}) was observed in U_p treatment (Prilled Urea), minimum specific gravity of potato (1.0602) observed in U_p treatment (Prilled Urea), minimum total soluble solid of potato (3.4940) was observed in U_s treatment (Urea Super Granule), firmness (31.898), dry matter content of tuber (19.533 g) were observed in U_p treatment (Prilled Urea).In case of skin color of potato minimum lightness (55.371) was observed in U_s treatment, the minimum redness to greenness (9.1933) was observed in U_p treatment, the minimum blackness (11.178) was observed in U_s treatment, the minimum chromaticity (14.547) was observed in U_p treatment, and the minimum Hue Augh (48.793) was observed in U_s treatment. In case of Flesh color minimum lightness (73.609) was observed in U_p treatment, the minimum redness to greenness (0.4211) was observed in U_s treatment, the minimum blackness (28.438), chromaticity (28.438), and Hue Augh (88.890) were observed in U_p treatment. Minimum Polyphenol (GA mg 100 g^{-1} FW) (57.312), starch (13.483 %) were observed in U_p treatment, minimum non reducing sugar (0.4223 mg g^{-1} FW) , reducing sugar (0.2472 mg g^{-1} FW) were observed in U_s treatment, and finally the minimum antioxidant (441.11 Trolox µg 100 g^{-1} FW) was observed in U_p treatment.

Result revealed that different growth, yield and quality characters of potato were significantly influenced by biochar levels. The maximum days to 50 % emergence of potato (19.183) was observed in B_0 treatment, maximum plant height (47.217 cm) was observed in B_4 treatment at 30 DAP, at 55 DAP (56.150 cm) from B_5 treatment and at 80 DAP (71.517 cm) was observed from B_4 treatment, maximum number of leaves of potato (50.810, 61.567 and 66.967 at 30, 55 and 80 DAP) was observed from B_5 treatment, maximum plant vigor at 55 DAP (9.2467) and maximum number of stem $hill^{-1}$ at 80 DAP (4.7002) were observed in B_4 treatment, crop maturity of potato (required 100.33 days), tuber $hill^{-1}$ of potato (9.2292), average tuber weight of potato (41.691 g), tuber yield of potato (35.489 t ha^{-1}), yield of marketable potato (34.018 t ha^{-1}) were observed in B_5 treatment. Biochar levels showed significant variation on category wise potato yield (t ha^{-1}), in case of cane potato (25-45mm), maximum potato yield (4.9733 t ha^{-1}) was observed from B_0 treatment, in case of Chips (45-75 mm), maximum potato yield (29.331 t ha^{-1}) was observed from B_5 treatment and in case of French fry (>75 mm) potato, maximum potato yield (0.3591 t ha^{-1}) was observed from B_4. Maximum specific gravity of potato (1.0924 g cc^{-1}) was observed in B_4 treatment, maximum total soluble solid of potato (4.3206) was observed in B_0 treatment, maximum firmness of potato (41.440 N) was observed in B_5 treatment, maximum dry matter content of tuber of potato (21.30 %) was observed in B_4 treatment. In case of skin color of potato the maximum lightness (57.030) was observed in B_4 treatment, the maximum redness to greenness (10.215) was observed in B_2 treatment, maximum blackness (11.713), chromaticity (15.363) was observed in B_0 treatment, and the maximum Hue Augh (51.970) was observed in B_3 treatment. In case of flesh color of potato maximum lightness (74.857) was observed in $B_{1,}$

maximum redness to greenness (0.6750) was observed in B_2 treatment, maximum blackness (29.907) was observed in B_5 treatment, maximum chromaticity (29.902) was observed in B_5 treatment and the maximum Hue Augh (89.305) was observed in B_0 treatment. Maximum Polyphenol (GA mg 100 g^{-1} FW) of potato (83.323), starch of potato (15.300 %) were observed in B_4 treatment, maximum non reducing sugar of potato (0.5034 mg g^{-1} FW) and reducing sugar of potato (0.4304 mg g^{-1} FW) were observed in B_0 treatment and maximum antioxidant of potato (502.01 Trolox µg 100 g^{-1} FW) was observed in B_4 treatment. Whereas minimum days to 50 % emergence of potato (14.717) was observed in B_5 treatment, minimum plant height (36.934, 43.417 and 55.584 cm at 30, 55 and 80 DAP), number of leaves of potato (34.60, 50.665 and 55.811 at 30, 55 and 80 DAP), plant vigor at 55 DAP (8.2567), stem $hill^{-1}$ at 80 DAP (3.6000), crop maturity of potato (required 94.83 days), tuber $hill^{-1}$ of potato (7.3466), average tuber weight of potato (29.335 g), tuber yield of potato (24.943 t ha^{-1}) were observed in B_0 treatment. In case of category wise of potato yield minimum yield of marketable potato (23.042 t ha^{-1}) was observed in B_0 treatment, minimum cane potato (25-45mm) yield (3.8214 t ha^{-1}) was observed from B_4 treatment, in case of Chips (45-75 mm) potato minimum potato yield (17.795 t ha^{-1}) was observed from B_0 treatment and in case of French fry (>75 mm) potato, minimum potato yield (0.1053 t ha^{-1}) was observed from B_2 treatment. Minimum specific gravity of potato (1.0139 g cc^{-1}) was observed in B_0 treatment, minimum total soluble solid of potato (3.2604) was observed in B_5 treatment, minimum firmness of potato (28.452 N), dry matter content of tuber of potato (16.80 %) were observed in B_0 treatment. In case of skin color of potato, minimum lightness (54.012) was observed in B_1 treatment, the minimum redness to greenness (8.698) was observed in B_3 treatment, the minimum blackness (10.780) and chromaticity (14.225) was observed in B_1 treatment and the minimum Hue Augh (48.352) was observed in B_2 treatment. In case of flesh color of potato the minimum lightness (72.383) was observed in B_3 treatment, minimum redness to greenness (0.3583) was observed in B_0 treatment, the minimum blackness (27.637), chromaticity (27.647) and the minimum Hue Augh (88.635) was observed in B_2 treatment. Minimum Polyphenol (GA mg 100 g^{-1} FW) of potato (34.531), starch of potato (12.050 %) were observed in B_0 treatment, minimum non reducing sugar of potato (0.3342 mg g^{-1} FW) and reducing sugar of potato (0.2042 mg g^{-1} FW) were observed in B_4 treatment, and minimum antioxidant of potato (379.39 Trolox µg 100 g^{-1} FW) was observed in B_0 treatment.

In this experimental result revealed that some of the specific characters showed significant effect, due to combined application of urea forms and biochar in the experimental field of potato which influences growth, yield and quality characters of potato. From the experiment result revealed that maximum days to 50 % emergence of potato (19.967) was observed in U_pB_0 treatment combination, maximum plant height (49.433, 60.333 and 74.233 cm) at 30, 55 and 80 DAP was observed from U_sB_5 treatment combination, Maximum number of leaves (55.037 and 66.600 at 30, 55 DAP) was observed from U_sB_5 treatment combination, Maximum plant vigor at 55 DAP (10.0) was observed from U_sB_4 treatment combination, maximum number of stem hill^{-1} at 80 DAP (5.0003) of potato was observed from U_pB_1 treatment combination, maximum days to crop maturity of potato (required 106.67 days), tuber hill^{-1} of potato (9.5417), average tuber weight of potato (44.966 g), tuber yield of potato (37.981 t ha^{-1}), yield of marketable potato (36.500 t ha^{-1}) were observed from U_sB_5 treatment combination. In case of category wise potato yield (t ha^{-1}) result revealed that cane (25-45 mm) potato, maximum yield (5.75 t ha^{-1}) was observed from U_sB_0 treatment combination, in case of Chips (45-75 mm) potato, maximum yield (31.550 t ha^{-1}) was observed from U_sB_5 treatment combination and in case of French fry (>75 mm) potato, maximum yield (0.4616 t ha^{-1}) was observed from U_pB_4 treatment combination. Maximum specific gravity of potato (1.0980 g cc^{-1}) was observed from U_sB_4 treatment combination, maximum total soluble solid of potato (4.4667) was observed from U_pB_0 treatment combination, maximum firmness of potato (45.367 N) was observed from U_sB_5 treatment combination, maximum dry matter content of tuber of potato (21.80 %) was observed from U_sB_4 treatment combination. In case of skin color maximum lightness (58.150) was observed in U_sB_4 treatment combination, maximum redness to greenness (11.447) was observed in U_sB_2 treatment combination, maximum blackness (12.037) was observed in U_pB_0 treatment combination, maximum chromaticity (15.393) was observed in U_sB_0 treatment combination, and maximum Hue Augh (52.797) was observed in U_pB_2 treatment combination. In case of flesh color, maximum lightness (74.597) was observed in U_pB_1 treatment combination, maximum redness to greenness (0.6800) was observed in U_sB_2 treatment combination, maximum blackness (30.650) and chromaticity (30.650) were observed in U_pB_5 treatment combination, and maximum Hue Augh (89.627) was observed in U_sB_5 treatment combination. Maximum Polyphenol of potato (87.523), starch of potato (15.900 %) were observed from U_sB_4

treatment combination, maximum non reducing sugar of potato (0.5067 mg g^{-1} FW) and reducing sugar of potato (0.5321 mg g^{-1} FW) were observed from U_pB_0 treatment combination, and maximum antioxidant of potato (509.23 Trolox µg 100 g^{-1} FW) was observed from U_sB_4 treatment combination.

Whereas minimum days to 50 % emergence of potato (14.467) was observed in U_sB_5 treatment combination, minimum plant height (35.30, 42.367 and 53.867 cm at 30 ,55 and 80 DAP), number of leaves of potato (34.333, 49.867 and 54.200 at 30 ,55 and 80 DAP), plant vigor at 55 DAP of potato (7.590) were observed from U_pB_0 treatment combination, minimum number of stem $hill^{-1}$ at 80 DAP (3.5330) was observed from U_sB_0 treatment combination, minimum days to crop maturity of potato (required 88.67 days), tuber $hill^{-1}$ of potato (7.2571), average tuber weight of potato (26.526 g) , tuber yield of potato (24.691 t ha^{-1}), yield of marketable potato (22.300 t ha^{-1}) were observed in U_pB_0 treatment combination. In case of category wise potato yield (t ha^{-1}), cane (25-45 mm) potato, minimum yield (3.3034t ha^{-1}) was observed from U_pB_4 treatment combination, in case of Chips (45-75 mm) potato, minimum yield (17.666 t ha^{-1}) was observed from U_sB_0 treatment combination, and in case of French fry (>75 mm) potato, no yield (0.0000 t ha^{-1}) was observed from U_sB_2 treatment combination which was statistically similar with $U_sB_{5,}$ and U_pB_1 treatment combination. Minimum specific gravity of potato (1.0012 g cc^{-1}) was observed from U_pB_0 treatment combination, minimum total soluble solid of potato (3.1332) was observed from U_sB_5 treatment combination, minimum firmness of potato (26.480 N) and dry matter content of tuber of potato (16.700 %) were observed from U_pB_0 treatment combination. In case of skin color minimum lightness (53.213) was observed in U_sB_3 treatment combination, minimum redness to greenness (8.340), blackness (10.130) and chromaticity (13.123) were observed in U_pB_1 treatment combination and minimum Hue Augh (43.907) was observed in U_sB_2 treatment combination. In case of flesh color minimum lightness (71.877) was observed in U_sB_3 treatment combination, minimum redness to greenness (0.3333) was observed in U_sB_0 treatment combination, and minimum blackness (26.917), chromaticity (26.927) and Hue Augh (88.590) were observed in U_pB_2 treatment combination. Minimum Polyphenol (GA mg 100 g^{-1} FW) of potato (33.864) was observed from U_pB_0 treatment combination, minimum starch of potato (10.400 %) was observed from U_pB_0 treatment combination, minimum non reducing sugar of potato (0.3109 mg g^{-1} FW) and reducing sugar of potato (0.1452 mg g^{-1} FW) were observed from U_sB_4 treatment combination, and minimum antioxidant of potato (366.47µg 100 g^{-1} FW) was observed from U_pB_0 treatment combination.

Conclusion

The result of the present experiment revealed that urea forms, biochar levels and combination of both showed the significant effect on some of the specific character of potato which influences the growth, yield and processing quality characters of potato. From the experiment, it may be said that Urea Super Granule (U_S) affect more in response of growth, yield and quality characters of potato than Prilled Urea (Up). Biochar can increase the soil carbon reserves, hold the soil nutrients, build the soil fertility, and increase the crop yield. From the experiment result revealed that different biochar levels influences growth, yield and quality characters of potato. Among the different levels B_4 (8 t ha^{-1}) treatment and B_5 (10 t ha^{-1}) treatment showed statistically similar result on most of the parameter.

In case of combination, the results in this present piece of work indicated that the plants performed better in respect of growth, yield and quality characters in both U_sB_5 and U_sB_4 treatment combination than control (U_sB_0 and U_pB_0). Although, the application of Urea Super Granule (U_S) along with 8 t ha^{-1} of biochar (B_4) application showed the best performance irrespective of yield and quality parameters but the application of Urea Super Granule (U_S) and 4 t ha^{-1} biochar (B_2) also satisfied the International processing standard *i.e.*, >20% dry matter, > 1.05 g cc^{-1} specific gravity and minimum reducing sugar (<0.3 mg g^{-1} FW). So, Bangladeshi potato farmers may apply Urea Super Granule (350 kg ha^{-1}) and 4 t ha^{-1} of biochar along with recommended dose of other inorganic fertilizers for producing processing quality potato without sacrificing yield.

Recommendation

Considering the facts of the present experiment, further studies in the following areas may be recommended:

1. Such study needed in different agro-ecological zones (AEZ) at Bangladesh for analogy the accurateness of the experiment.
2. Long durated experimentation with bio-char is suggested to know its residual values and also to find out the nutrient composition of biochar derived from different sources of organic manures.

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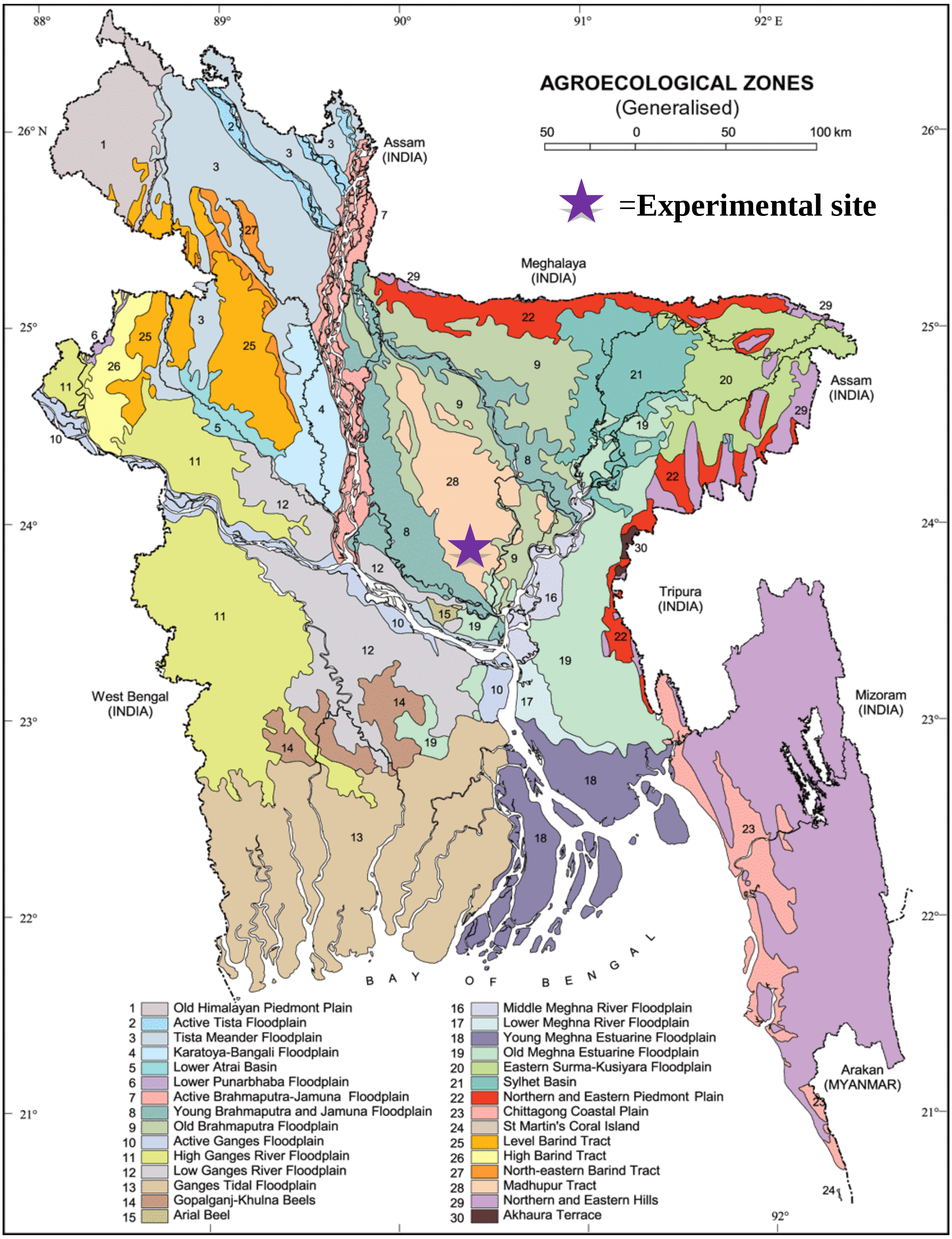
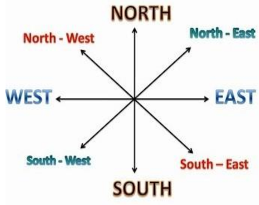
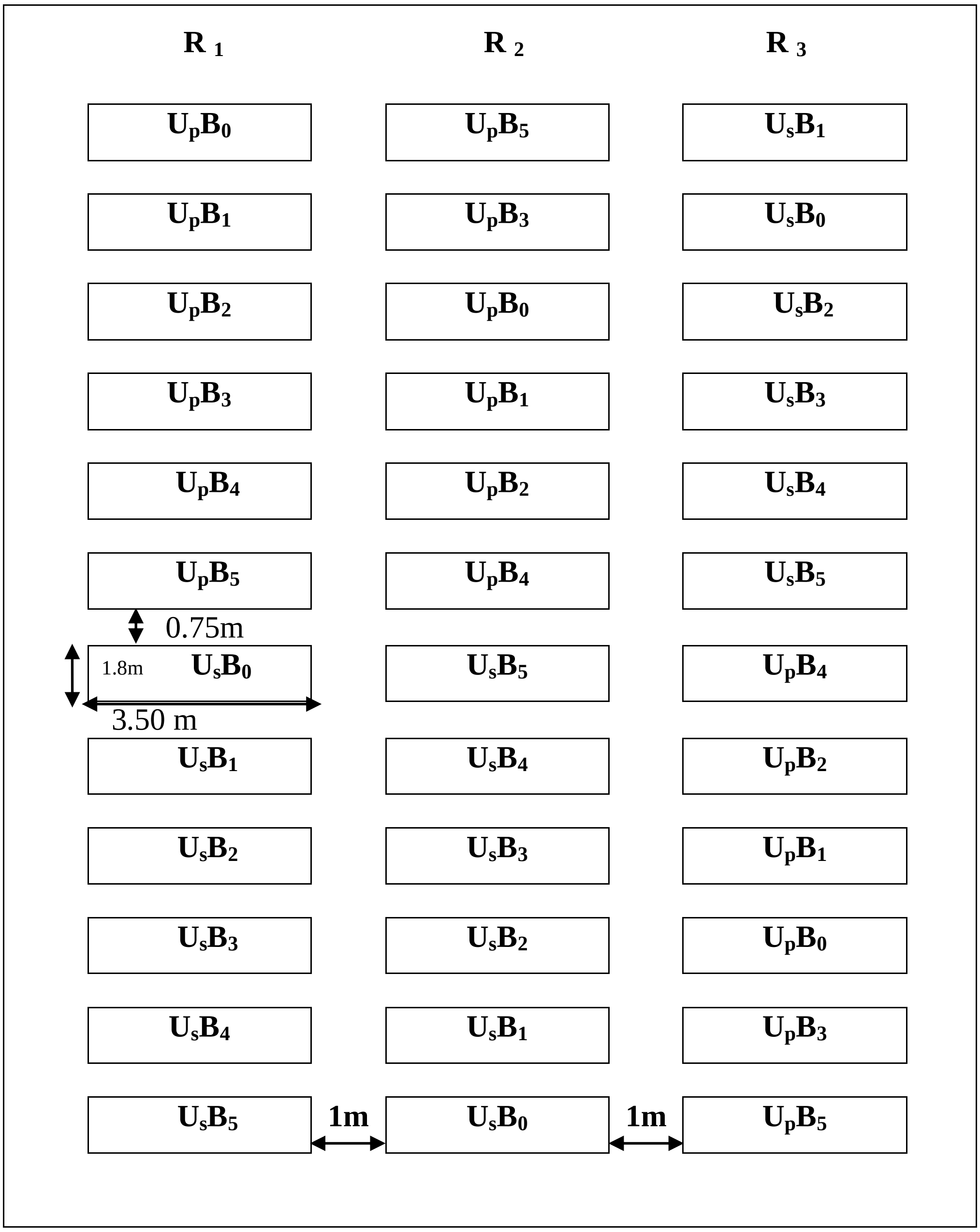
APPENDICES

Appendix I. Map showing the experimental site under study





Appendix II. Layout of the experiment field



LEGEND

Up- Prilled urea, Us- Urea Super granules, B0- Control, B1- 2 t/ha, B2- 4 t/ha, B3- 6 t/ha, B4-8 t/ha, B5- 10 t/ha

Appendix III. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

Appendix IV. Monthly meteorological information during the period from October 2018 to March, 2019

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	October	27.26	16.30	64	43
	November	25.50	6.70	54.75	0.0
	December	23.80	11.70	46.20	0.0
2019	January	22.75	14.26	37.90	0.0
	February	35.20	21.00	52.44	20.4
	March	34.25	24.50	44.20	57.6

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix V. Analysis of variance of the data on Days to 50% emergence and plant height of potato as influenced by urea forms and biochar levels

Source	Df	Mean square of, Days to 50% emergence	Mean square of plant height at		
			30 DAP	**55 DAP**	**80 DAP**
Replication (R)	2	0.0064	5.072	5.244	10.111
Urea forms (N)	1	10.5593**	168.996*	313.278**	81.902*
Error (R×N)	2	0.0206	1.798	1.837	3.721
Biochar levels (B)	5	17.3254**	85.087**	134.736**	234.500**
N×B	5	0.3239^{NS}	1.400 ^{NS}	7.364*	6.055 ^{NS}
Error (R×N×B)	20	2.5079	9.933	10.355	21.350
Total	35				

^{NS}: Non Significent

**Significant at 1% level of significance

*Significant at 5% level of significance

Appendix VI. Analysis of variance of the data on leaf number of potato as influenced by urea forms and biochar levels

Mean square of No of Leaf at				
Source	Df	**30 DAP**	**55 DAP**	**80 DAP**
Replication (R)	2	3.286	0.018	0.684
Urea forms (N)	1	118.788**	229.083**	160.736**
Error (R×N)	2	4.064	0.005	0.606
Biochar levels (B)	5	308.221**	126.128**	116.105**
N×B	5	21.121 ^{NS}	21.526 ^{NS}	3.934 ^{NS}
Error (R×N×B)	20	13.711	21.364	26.348
Total	35			

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix VII. Analysis of variance of the data on Plant vigor (1-10), Number of stem hill^{-1} and days to crop maturity of potato as influenced by urea forms and biochar levels

Mean square of				
Source	Df	**Plant vigor (1-10) At 55 DAP**	**Number of stem hill^{-1} at 80 DAP**	**Days to crop maturity**
Replication (R)	2	0.5257	0.04925	25.33
Urea forms (N)	1	16.9332*	0.09030 ^{NS}	1332.25**
Error (R×N)	2	0.6453	0.03170	6.33
Biochar levels (B)	5	1.0828**	1.03882**	31.92**
N×B	5	0.0257 ^{NS}	0.56750*	0.72
Error (R×N×B)	20	0.0342	0.16172	0.90
Total	35			

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix VIII. Analysis of variance of the data on no of tuber hill^{-1}, Average tuber weight and tuber yield of potato as influenced by urea forms and biochar levels

Mean square of				
Source	Df	**No of tuber hill^{-1}**	**Average tuber weight (g)**	**Tuber yield (t ha^{-1})**
Replication (R)	2	0.14845	3.735	3.040
Urea forms (N)	1	2.44141*	225.240**	214.769**
Error (R×N)	2	0.05573	1.212	1.071
Biochar levels (B)	5	3.02424**	132.784**	89.754**
N×B	5	0.06281 ^{NS}	5.026 ^{NS}	9.418*
Error (R×N×B)	20	0.27543	6.936	6.028

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix IX. Analysis of variance of the data on category wise potato yield of potato as influenced by urea forms and biochar levels

Mean square of Category wise potato yield (t ha^{-1}) for					
Source	Df	**Yield of marketable potato (>20 g)**	**Cane (25-45 mm)**	**Chips (45-75 mm)**	**French fry (>75 mm)**
Replication (R)	2	2.235	0.01005	2.174	0.00027
Urea forms (N)	1	180.038**	4.24003	129.569**	0.00068
Error (R×N)	2	1.021	0.30298	0.790	0.00025
Biochar levels (B)	5	93.058**	1.02686**	107.802**	0.05222**
N×B	5	4.103*	0.42646	6.898*	0.07785**
Error (R×N×B)	20	5.308	0.24487	4.015	0.00059

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix X. Analysis of variance of the data on quality characters of potato as influenced by urea forms and biochar levels

Mean square of Quality characters					
Source	Df	**Dry matter (DM)**	**Specific gravity (SG)**	**Firmness (N)**	**Total soluble solid (^{0}Brix)**
Replication (R)	2	6.0208	2.243E-05	0.499	0.00892
Urea forms (N)	1	3.6100**	7.747E-04*	278.740**	0.49815*
Error (R×N)	2	0.0008	3.946E-05	0.376	0.01074
Biochar levels (B)	5	16.0980**	4.538E-03**	181.613**	0.92461**
N×B	5	0.1540**	1.466E-04*	5.998 ^{NS}	0.00771 ^{NS}
Error (R×N×B)	20	0.0148	3.812E-05	8.259	0.11236

Appendix XI. Analysis of variance of the data on skin color of potato as influenced by urea forms and biochar levels

Mean square of skin color of potato						
Source	Df	**Lightness (L)**	**Redness to Greenness (a)**	**Black**	**chromaticity**	**Hue Augh (^{o})**
Replication (R)	2	1.21445	0.26079	0.74020	0.27492	6.0526
Urea forms (N)	1	1.15562 ^{NS}	3.87434 ^{NS}	0.00321^{NS}	1.12714 ^{NS}	23.5548 ^{NS}
Error (R×N)	2	0.73391	0.43944	0.81610	1.48767	2.0388
Biochar levels (B)	5	7.22438 ^{NS}	1.59087 ^{NS}	0.63478^{NS}	1.11447 ^{NS}	10.1610 ^{NS}
N×B	5	5.90478 ^{NS}	2.53534 ^{NS}	1.01026^{NS}	1.55796 ^{NS}	27.4316 ^{NS}
Error (R×N×B)	20	3.95926	1.30694	1.77705	2.11209	19.4964

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix XII. Analysis of variance of the data on flesh color of potato as influenced by urea forms and biochar levels

Mean square of flesh color of potato						
Source	Df	**Lightness (L)**	**Redness to Greenness (a)**	**Black**	**chromaticity**	**Hue Augh (^{o})**
Replication (R)	2	3.32302	0.27604	0.07501	0.03810	1.22156
Urea forms (N)	1	0.00934 ^{NS}	0.16810 ^{NS}	1.06090^{NS}	1.17361 ^{NS}	0.70560 ^{NS}
Error (R×N)	2	2.08435	0.05396	1.75093	1.70034	0.19726
Biochar levels (B)	5	3.93445 ^{NS}	0.09807 ^{NS}	3.96610^{NS}	3.84999 ^{NS}	0.45860*
N×B	5	0.59548 ^{NS}	0.02904 ^{NS}	1.52251^{NS}	1.53395 ^{NS}	0.06813 ^{NS}
Error (R×N×B)	20	1.21002	0.03653	2.81321	2.80330	0.14115

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

Appendix XIII. Analysis of variance of the data of some biochemical parameters of potato as influenced by urea forms and biochar levels

Mean square of						
Source	Df	**Polyphenol (GA mg 100 g^{-1} FW)**	**Starch (%)**	**Non Reducing Sugar (mgg^{-1}FW)**	**Reducing Sugar (mgg^{-1}FW)**	**Antioxident (Trolox µ Mol 100 g^{-1} FW)**
Replication (R)	2	5.87	6.16333	0.21327	0.00014	82.5
Urea forms (N)	1	256.70**	11.9025**	0.00050 ^{NS}	0.10798**	1628.9*
Error (R×N)	2	0.18	2.956E-31	0.00010	0.00012	58.6
Biochar levels (B)	5	2403.69**	8.80450**	0.02521**	0.04308**	17422.5**
N×B	5	20.00**	1.93650**	0.00066 ^{NS}	0.00533**	97.4 ^{NS}
Error (R×N×B)	20	0.35	9.667E-03	0.00077	0.00034	1015.3

^{NS}: Non Significent
**Significant at 1% level of significance
*Significant at 5% level of significance

SOME PICTORIAL VIEW OF THE EXPERIMENT

Preparation of the research field

Planting of potato tuber in the field

Field view at vegetative stage

Field view at later vegetative stage

Signboard of the experiment field

Weighing of the potato during harvest

Pile of potato tuber after harvest

Post harvest data collecting

Treatment wise potato tuber