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Applying biochar and different form of nitrogen: be a good agricultural practice for better yield and processing quality of potato

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ABSTRACT

Purpose: Produced tubers with inferior quality are the main bottleneck for exporting surplus amount of potato to the importing countries. Applying nitrogen as prilled and super granule urea along with biochar may improve the yield and processing quality of potato. To generalize a partial solution, the study was conducted to find out the efficiencies of N forms and biochar towards the improvement of the processing quality of potato for export. **Research Method**: The experiment comprised two factors. Factor A: Nitrogen form (2): Prilled Urea (Up) and Urea Super Granule (U_S), and Factor B: Biochar level (6): B_0-Control, B_1- 2 t/ha, B_2- 4 t/ha, B_3- 6 t/ha, B_4-8 t/ha, and B_5- 10 t/ha. The experiment was laid out in a split-plot design with three replications. **Findings**: Nitrogen form and/or biochar levels had shown significant influence on most of the parameters. The maximum tuber yield of potato (37.9 t ha^{-1}) was observed from U_sB_5 which was statistically similar to U_sB_4. The maximum dry matter content of tuber (21.8 %) and specific gravity of potato (1.098 g/ml) were observed from U_sB_4. So, it may be concluded that the application of urea super granule (U_S) plus biochar B_4 (8 t/ha) was found best combination for maintaining optimum yield and better processing quality of potato. **Research limitations**: No limitations to report. **Originality/Value**: Application of biochar improved the soil organic carbon status (data not shown) and exhibited better potato yield and qualities. Urea super granules (USG) are much economic and environmental friendly over prilled urea.

INTRODUCTION

Potato (*Solanum tuberosum* L.) prominently known as alu 'The king of vegetable', is a tuber crop belongs to the family Solanaceae. 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). The yield of potato in Bangladesh is very low (20.61 t ha^{-1}) in compared to those 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 by the farmers has also deteriorated the soil health and soil organic carbon which is a threat to soil sustainability (Sujatha et al., 2014). Biochar is a black carbon manufactured through pyrolysis of biomass (Lehmann et al., 2006), is one of the best soil amendments that can improve soil fertility (Ding et al., 2016; Hunt et al., 2010). Nitrogen (N) 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. Nitrogen (N) is beneficial for its growth, development (Yousaf et al., 2017) and protein synthesis (Arnold et al., 2015). The farmers of Bangladesh grown potato in different regions through prilled urea with other fertilizers. Using of Urea Super Granule (USG) technology may be a cost effective and environment friendly approach. Deep placement of USG effectively increases N use efficiency (31.7%) that does can save 30% nitrogen than prilled urea, increase absorption rate, improve soil health and ultimately increase the yield (Jaiswal & Singh, 2001) because lower amount of nitrogen losses from USG than surface broadcasting of prilled urea. Dou et al. (2012) revealed that biochar treatment could increase yield, sugar content and appearance quality of sweet potato. Upadhyay et al. (2020) also reported that, the application of biochar has improved the production of potato. The organic matter of most of the soils of Bangladesh is below 2% as compared to an ideal minimum value 4% (Bhuiyan, 1994). 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 resulted better carbon amount in soil. Considering the above facts, the present work was conducted to evaluate the effect of nitrogen form and biochar level and their interaction on yield and processing quality of potato.

MATERIALS AND METHODS

Experimental site

The experiment was conducted at the agronomy research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during November 2019 to March 2020. 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 area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during rainy season and scanty rainfall during the rest period of the year. The top soil was characterized by silty clay in texture, olive- gray whitish with common fine to medium distinct dark whitish brown mottles and the soil had pH- 6.3 and organic carbon- 1.8%.

Experimental treatments and design

The experiment consisted two factors *viz*., factor A: Nitrogen form (2): U_p= Prilled urea and U_s= Urea Super Granule; factor B: Biochar Level (6): B_0 = Control, B_1 = 2 t/ha, B_2 = 4 t/ha, B_3 = 6 t/ha, B_4 = 8 t/ha and B_5 = 10 t/ha. The experiment was laid out in split-plot design

where nitrogen forms assigned to main plot and biochar level to subplot having 3 replications. The size of each unit plot was 2.6 m × 1.2 m where 60 cm and 25 cm was the crop spacing.

Crop husbandry

BARI Alu- 29 (Courage) was as test crop. The land of the experimental field was first opened on November 11, 2019 with a power tiller. The soil was treated with Furadan 5G as 20 kg ha^{-1} when the plot was finally ploughed to protect the young plant from the attack of cut worm. Seeds were treated with Provex-200as 0.25% before sowing to prevent seeds from the attack of soil borne disease. Healthy and uniform sized potato tuber seeds were collected and then planted in a hole at a depth of 3-4 cm on November 24, 2019. The crop was fertilized by all common fertilizers as per recommendation of TCRC (2004). Including others fertilizers half amount of urea was (175 kg ha^{-1}) applied at basal doses during final land preparation. The remaining 50% prilled urea was side dressed in two equal splits during first (at 25 days after planting-DAP) and second (at 45 DAP) earthing up. The urea super granule was applied per plant in two split, first split is during the land preparation and second split were applied at 45 DAP. From 350 kg of total nitrogen, 330 kg nitrogen was supplied from urea as prilled and as urea super granule and rest 20kg was supplied from cowdung (0.50% N) as 10 t ha^{-1}. Different dose of biochar were applied as per treatment during final land preparation. Earthing up was done twice (25 and 45 DAP, respectively) during growing period and others intercultural operation were done as per when needed. Haulm cutting was done at February 18, 2020 at 85 DAP, when 60-70% plants showed senescence and the tops started drying. After haulm cutting the tubers were kept under the soil for 7 days for skin hardening. 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.

Recording of data

Yield of table potato ha^{-1}

The yield of potato was measured by the weight of tubers from a plot which was recorded in kilogram and converted to t ha^{-1}**.** The tuber below 20g was discarded for measuring categories of tuber.

Category of potato tubers for various uses

Tubers harvested from each treatment were classified for different purposive uses on the basis of diameter *i.e*., canned 20-30 mm, flakes 30-45 mm, chips 45-75 mm, french fry>75mm (Marwaha et al., 2010) and expressed in percentage. A special type of frame (potato riddle) was used to differentiate the potato tuber.

Dry matter content of potato tubers

At first selected tubers were collected, weighted and cut into several pieces and was dried under sunshine for 3 days then dried in an oven at 72^0C for 72 hours. The sample was then transferred into desiccators and allowed to chill down at temperature. Then ultimate weight of the sample was taken into percent. The dry matter contents in potato tubers were computed by following (Elfnesh et al., 2011).

Estimation of specific gravity of potato tubers

Specific gravity was determined from the raw tubers according to weight under water (at 4°C) method as described by Solaiman et al. (2015).

Firmness in potato tubers

Firmness was estimated by using pressure gauge (Model FG-5000). For the estimation of firmness firstly the potato tubers were divided into two part then created pressure using pressure gauge and recorded the reading as N (Neuton).

Estimation of Total Soluble Solids (TSS) in potato tubers

Total Soluble Solids (TSS) of potato tuber was measure just after harvesting of tuber and a drop of potato juice was placed on the glass eye of Hand Sugar Refractometer "ERMA" Japan, Range: 0-32% consistent with (AOAC, 1990) and recorded as ^{o}Brix from direct reading of the instrument.

Statistical analysis

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

RESULTS

Tuber yield

Different nitrogen form showed significant effect on tuber yield (t ha^{-1}) of potato (data not shown). Biochar levels showed significant effect on tuber yield (t ha^{-1}) of potato (data not shown). Combined effect of nitrogen form and biochar levels showed significant effect on tuber yield (t ha-^{1}) of potato. Result revealed that the maximum tuber yield of potato (37.9 t ha^{-1}) was observed from U_sB_5 treatment combination which was statistically similar with U_sB_4 followed by U_sB_3 and U_sB_2 whereas the minimum (24.7 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 (Table 1).

Category wise potato yield

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 nitrogen form in the experimental field (data not shown). Biochar level showed significant variation (data not shown) on category wise potato yield (t ha^{-1}). 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 nitrogen form and biochar level on the experimental field. 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 (31.6 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 (0.462 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. In respect of cane potato, the minimum yield (3.30 t ha^{-1}) was observed from U_pB_4 treatment combination, in case of chips potato, the minimum yield (17.7 t ha^{-1}) was observed from $U_sB_0$and U_pB_0 treatment combination, and in case of french fry potato, the minimum yield (0.0000t ha^{-1}) was observed from U_sB_2 treatment combination which was statistically similar with U_sB_5, and U_pB_1 (Table 1).

Table 1. Combined effect of nitrogen form and biochar level on tuber yield and category wise potato yield cv BARI alu-29

Treatment combinations	Tuber yield (t ha^{-1})	Category wise potato yield (t ha^{-1}) for		
		Cane (25-45 mm)	Chips (45-75 mm)	French fry (>75 mm)
U_pB_0	24.691 f	4.1967	17.923 e	0.1800 e
U_p B_1	27.670 ef	4.3020	22.581 d	0.4429 a
U_p B_2	26.982 ef	3.5956	22.726 d	0.2106 de
U_p B_3	29.879 de	3.8590	24.360 cd	0.2454 cd
U_p B_4	32.972 cd	3.3034	27.507 bc	0.4616 a
U_p B_5	32.997 cd	4.2176	27.111 bc	0.2095 de
U_s B_0	25.195 f	5.7500	17.666 e	0.3700 b
U_s B_1	33.423 bcd	4.4300	27.213 bc	0.2146 de
U_s B_2	35.187 abc	4.2925	28.785 ab	0.0000 f
U_s B_3	35.263 abc	4.2891	28.685 ab	0.3981 b
U_s B_4	37.452 ab	4.3394	31.076 a	0.2565 c
U_s B_5	37.981 a	4.4915	31.550 a	0.4585 a
LSD $_{(0.05)}$	4.1816	NS	3.4129	0.0412
CV (%)	7.76	11.63	7.83	8.43

Note: 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, B_2- 4 t/ha, B_3- 6 t/ha, B_4- 8 t/ha, B_5- 10 t/ha

Dry matter content of potato tuber

Dry matter content of potato tuber (%) significantly influenced by nitrogen form (data not shown). Biochar level showed significant variation (data not shown) on dry matter content of potato tuber (%). Combined effect of nitrogen form and biochar level showed significant effect on dry matter content of potato tuber (%) of potato. From the experiment result revealed that the maximum dry matter content of potato tuber (21.80 %) was observed from U_sB_4 treatment combination which was statistically similar with U_sB_5 treatment combination. Whereas the minimum dry matter content of potato tuber of potato (16.700 %) was observed from U_pB_0 treatment combination (Table 2).

Specific gravity

A significant effect on specific gravity of potato was found due to nitrogen forms (data not shown). Biochar levels showed significant variation on specific gravity of potato (data not shown). Combined effect of nitrogen form and biochar level showed significant effect on specific gravity of potato. From the experiment result revealed that the maximum specific gravity of potato (1.098 g/ml) 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/ml) was observed from U_pB_0 treatment combination (Table 2).

Firmness

Firmness of potato tuber was profoundly influenced by nitrogen forms (data not shown). Biochar levels showed significant variation on firmness of potato (data not shown). Combined effect of nitrogen form and biochar level showed non-significant effect on firmness of potato. 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 (26.480 N) was observed from U_pB_0 treatment combination (Table 2).

Table 2. Combined effect of nitrogen form and biochar level on processing qualities of potato cv BARI alu-29

Treatment	Dry matter (DM, %)	Specific gravity (SG)	Firmness (N)	Total soluble solids (°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

Note: 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, B_2- 4 t/ha, B_3- 6 t/ha, B_4- 8 t/ha, B_5- 10 t/ha

Total soluble solids

Due to nitrogen forms a significant effect was found on total soluble solids of potato (data not shown). Biochar level showed significant variation on total soluble solids of potato (data not shown). Combined effect of nitrogen form and biochar level showed non-significant effect on total soluble solids of potato. From the experiment result revealed that the maximum total soluble solids of potato (4.4667 °Brix) was observed from U_pB_0 treatment combination. Whereas the minimum total soluble solids of potato (3.1332 °Brix) was observed from U_sB_5 treatment combination (Table 2).

DISCUSSION

Being nitrogen is more mobile in soil so there are more losses of nutrient status from nitrogen in soil. The application of nitrogen as prilled urea resulted greater losses due to its readily availability in soil whereas urea super granules (USG) imparted a slow release option for nitrogen in soil. As a result, the soil gets more nitrogen from super granules than prilled form to improve the crop growth and development. Nahar et al., (2015) reported that, in dry land rabi crops like wheat the deep placement of slow releasing nitrogenous fertilizer such as USG exhibited lower nitrogen loss as well as showed an increased efficiency. They also reported that, the optimum application of USG can increase yields and fertilizer-N utilization of wheat over prilled form. On crop growth and soil fertility, the biochar application along with N fertilization exhibited beneficial effects (Ali et al., 2020**)**. The combined application of biochar and N exhibited a 10% increase in barley yield over no biochar addition. Leaf physiology, growth, and yield may significantly change from the integration of N with biochar. They also pointed out a similar trend for wheat and potatoes under the influence of biochar. These findings are in agreement with our present findings. 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**)**. The maximum potato yields (30.5 t ha^{-1}) could be achieved by the combined application of biochar and recommended dose of

nitrogenous fertilizers in comparison with the control treatment (Farooque et al., 2020**)**. Our study also showed a significant increase in potato yield by biochar application in combination with recommended dose of nitrogen as super granule form. Plant growth, yield and quality have been increased with the application of biochar treating (Gupta et al., 2020, Silva et al., 2017). A general trend was found in potato cv. Atlantic, where yields was increased with the increasing of biochar application rates (Nair & Lawson, 2015**)**. Improved vegetative growth, tuber yield and its components with good tubers quality was exhibited in potato with the addition of biochar to the field (Youseef et al., 2017, El-Metwaly, 2020). The research findings are much limited in Bangladesh about biochar and nitrogen forms on the tuber production of potato crop, so we have described the probable reasons of such results below as per our own speculative ideas but these descriptions are in agreement with the reasons pointed out by above citation of researchers. Higher nitrogen accumulation from urea super granule has increased the weight of individual tuber which might have given higher tuber yield per hectare. Application of biochar might have increased the tuber bulking than prilled urea which in turns increased the tuber yield per hectare. 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. 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. Applying biochar might have increased the tuber texture and total soluble solids which in turns increased the percent of dry matter content. 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. Application of biochar might have increased the tuber bulking than prilled urea which in turns increased the tuber specific gravity. Optimum accumulation of nitrogen from urea super granule might have increase the tuber texture which in turns gave lower mouth pressure to bite by teeth. The application of biochar might also have increased the tuber texture resulting needs lower hardiness to bite by teeth. Higher nitrogen accumulation from urea super granule along with biochar might have increased the accumulation of tuber starch which in turns might have increased the total soluble solids content of tuber.

CONCLUSION

From the experiment it may be concluded that nitrogen form, biochar levels and their combination showed significant effect on most of the parameters studied. Result exhibited that Urea Super Granule (U_S) affect more in response of yield and processing quality of potato than Prilled Urea (Up). Biochar might have been increased the soil carbon reserves, hold the soil nutrients, built the soil fertility which may resulting in increased tuber yield. Although U_sB_5 and U_sB_4 treatment combination showed statistically similar results but on the basis of economic point of view U_sB_5 treatment combination needed more biochar application (2 t/ha extra) than U_sB_4 treatment combination and that increases production cost. So finally it can be said that the combined application of Urea Super Granule (U_S) + Biochar B_4 (8 t/ha) was found to be most suitable and may be economic to produce potato in AEZ-28 of Bangladesh.

Conflict of interest

No part of this research has been published elsewhere in any form. So, the authors declared that they have no conflict of interest.

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