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RESEARCH ARTICLE

NUTRIENT COMBINATION WITH BIOCHAR: IMPROVING YIELD AND QUALITY OF JUTE SEED

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ABSTRACT

Plants are naturally growing on the soil without hampering the eco-friendly environment. Intensive cultivation of crops with high yielding varieties (HYV) hampering the soil health resulting infertile soil. In addition, frequent uses of chemicals as well as overdose of synthetic fertilizer creating hazardous environment for the living things. However, to meet up the demand of foods as well as other basic requirements of increasing population of the world crop cultivation techniques need to be modernized. To overcome this situation, application of organic fertilizer need to apply regularly. Biochar can be a good source of organic fertilizer and it is currently using to improve the soil health globally. To examine the effect of biochar on jute growth and yield an experiment was set up in two different locations (Jute Agriculture Experimental Station (JAES), Manikganj, and Jute Research Sub Station (JRSS), Jashore of Bangladesh) during the period from August to December, 2019. Results revealed that location (JAES) had significant and positive effect on jute physiology and seed yield and as well as seed quality. Among fourteen treatments, treatment T₂ (Recommended dose of fertilizer (RDF)) showed the highest plant height (163.5 cm), base diameter (7.44 mm) and pod per plant (16.5) compare to the rest treatments. Treatment T₆ (RDF 75% + 25% biochar@3.0tonha⁻¹) showed the best seed weight (2.13 g) and seed yield/ plant (3.98 g) among all treatments. Interaction among treatments and locations, T₂ x L₂ affected seed germination (99%) and field emergence (92.33%) positively. From this research it was cleared that biochar alone may not enough but combination is required for improving jute seed yield and quality.

KEYWORDS

Biochar, location, jute growth, seed yield, seed quality and seed germination.

1. INTRODUCTION

Jute (*Corchorus* spp.) belonging to the family Malvaceae, is one of the important fibre and cash crops of Bangladesh (Islam and Ali, 2017). In agricultural sector of Bangladesh, jute is called golden fibre because of earning foreign currency to strong the national GDP (Anonymous, 2013). Jute covers around 80% of bast fibre production world-wide (FAO, 2014). Jute fiber is well known for its versatility, durability and fitness and fiber is used for making different type of products including carpet, mat and cloths (Zhang et al., 2013). In addition, young leaves of jute are popular as vegetables because of containing several proteins, vitamins, minerals and antioxidants (Islam, 2007; Mollah et al., 2020; Tareq et al., 2019). Study also showed that jute plant has significant importance for pharmacological research as it contained several secondary metabolites important for human health issues (Al-Snafi, 2016).

Jute had a significant contribution to the national economy of Bangladesh. However, total area of land under jute cultivation is decreasing continuously due to the more production of food crops and moreover jute price is not attractive compare to other crops in Bangladesh (Hossain et al., 2017). In addition, availability of quality seed and total yield also affected jute production in Bangladesh (Sikder et al., 2008). Recently, Bangladesh government has employed policy to promote investment and

export of jute products to regain the lost position of jute in the world market (Islam and Ali, 2017). Recently increasing trend of jute cultivation has been observed in last few years because of gaining profit in jute cultivation (Hossain et al., 2017). Moreover, Bangladesh Jute Research Institute released new variety BJRI tossa pat-8 is playing an important role in solving the both problems.

Jute cultivation is highly favored by the environment of Bangladesh. However, jute production is also dependent on the area or location of jute cultivation (Rashid et al., 2007). Jute requires total 1500 mm or more rainfall/ water and minimum 250 mm water of each month during jute growing season in summer (<http://en.banglapedia.org/index.php?title=Jute>). Jute can be grown in different types of soil ranging from clay to sandy loam. Bangladesh Jute Research Institute (BJRI) applied different dose of fertilizer based on the varietal recommendation (Islam and Rahman, 2008). Jute plant need adequate amount of essential nutrients for optimum plant growth and development leading to yield however, continuous application of N, P and K can create imbalance effect of nutrients leading to decrease fertilizer efficiency (Lin et al., 2019; Ali et al., 2019). To overcome this problem application of biochar might be one of the proper solutions to solve this problem.

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Biochar is the solid product of incomplete combustion of in an oxygen limited environment, which is widely using in agricultural sector (Hussain et al., 2017; Zhu et al., 2014). Application of biochar to the soils can potentially help to reduce climatic change and concurrently improve soil function leading to high crop production (Nair et al., 2017; Verheijen et al., 2009). In addition, biochar application increase soil water-holding capacity, enhanced soil water permeability, increase saturated hydraulic conductivity (SHC), reduced soil strength as well as modify soil bulk density (Asai et al., 2009; Chan et al., 2007; Laird et al., 2010). Biochar can also increase nutrient availability of plants by changing the physical and chemical properties of soils which help to root colonization by mycorrhizal fungi (Yamato et al., 2006). In addition, biochar may also reduce emissions of greenhouse gases from soil such as N₂O and CH₄ leading to eco-friendly environment (Lehmann and Rondon, 2006).

Improvement of crop yield in agricultural sector can be achieved by soil improvement through using biochar (Srinivasarao et al., 2013). Biochar increase N availability in soil, reduce leaching loss of N by retain water however, N can be improved by application of biochar produced from slow pyrolysis rather than fast pyrolysis (Bruun et al., 2012). It was reported that biochar increases the crop yield without hampering the existing natural environment (Rawat et al., 2019). Report showed that application of biochar increases the yield of tomato significantly compare to the control treatment (Yilangai et al., 2014). In addition, vegetable yield was increased by 5%-25% with the using of biochar than the traditional agricultural practices (Vinh et al., 2014). Recent research on mung bean with biochar revealed the positive effect of biochar on mung bean physical growth and yield (Toma et al., 2017). However, effect of biochar on the jute production and seed quality is still unknown. So, this experiment was conducted to see the effect of biochar and geographical location on jute variety BJRI tossa-8 seed yield and quality.

2. MATERIALS AND METHODS

The experiment was conducted at the Jute Agriculture Experimental Station, Manikganj, and Jute Research Sub Station, Jashore of Bangladesh Jute Research Institute (BJRI), Bangladesh during the period from August to December, 2019. BJRI tossa pat-8 was used for this research and seeds were collected from Bangladesh Jute Research Institute (BJRI), Manik Mia Avenue, Dhaka. The research was laid out in randomized complete block design (RCBD) with three replications. A total 14 treatment combinations were applied for this experiment (Table 1). The experimental plot was 3.1 m × 3.1 m in size. At the beginning of the experiment, the soil was ploughed in two directions and smoothed. Seeds were sown on 10th August, 2019

after seed treating with Vitavax 200® (0.04%). All cultural operations were according to Chowdhury and Hassan (2013). Jute was harvested on 30th December, 2019. Data were subjected to ANOVA using MSTAT-C (Gomez and Gomez, 1984). Treatment means were separated with LSD (Least significant difference). Correlation studies were carried out using STAR software (ver. 2.0.1, IRRI, Los Banos, Laguna, Philippines).

Table 1: Treatments combinations used in this experiment.

- T₁=Control (No fertilizer),
- T₂=RDF (Recommended dose of fertilizer),
- T₃=Biochar@3.0tonha-1
- T₄=Biochar@5.0tonha-1
- T₅=Biochar@8.0tonha-1
- T₆=RDF 75% + 25% Biochar@3.0tonha-1
- T₇= RDF 75% + 25% Biochar@5.0tonha-1
- T₈= RDF 75% + 25% Biochar@8.0tonha-1
- T₉= RDF 50% + 50% Biochar@3.0tonha-1
- T₁₀= RDF 50% + 50% Biochar@5.0tonha-1
- T₁₁= RDF 50% + 50% Biochar@8.0tonha-1
- T₁₂= RDF 25% + 75% Biochar@3.0tonha-1
- T₁₃= RDF 25% + 75% Biochar@5.0tonha-1
- T₁₄= RDF 25% + 75% Biochar@8.0tonha-1

3. RESULTS

3.1 Effect of location on vegetative growth, seed yield and seed quality of jute

Locations showed significant effect on plant height (Table 2). The highest plant height (274.74 cm) and base diameter (9.08) was recorded in Jute Agriculture Experimental Station (JAES), Manikganj whereas the lowest was recorded in Jute Research Sub-Station (JRSS), Jashore. In addition, branches per plant, pod per plant was higher in JAES, Manikganj. However, plant population per plot was not affected by the locations. Interestingly, pod length was higher in JRSS, Jashore (6.64 cm). Number of seed in each pod was similar but seed yield per plant was higher in JAES, Manikganj (3.5 g). Seed size normally determine the seed weight. Weight of thousands of seed was higher in JRSS (2.20 g), Jashore compare to the seeds of JAES, Manikganj (1.88 g) (Table 3). However, percent of germination (90%) and field emergence percent (83%) of seeds were higher in JAES, Manikganj (Table 3). These results clearly suggesting that location had significant effect on vegetative growth of jute, seed yield as well as seed quality

Table 2: Effect of location on yield and yield contributing characters of jute seed.

Location Name	Plant height (cm)	Base Diameter (mm)	Plant population / plot	Branches / plant	Pod / plant	Pod length (cm)	Pod diameter (mm)	No. of seed per pod	Seed yield per plant (g)
JRSS	76.12b*	5.03b	167.57a	2.65b	9.66b	6.64a	4.91b	172.81a	3.05b
JAES	234.74a	9.08a	168.55a	3.43a	21.44a	6.270b	5.09a	176.86a	3.50a
%CV	9.68	11.90	11.97	14.79	19.23	6.21	4.68	9.87	19.75
LSD	6.59	0.37	12.18	0.20	1.31	0.18	0.10	7.56	0.28

Note: JRSS: Jute Research Sub-Station, Monirampur, Jashore; JAES: Jute Agriculture Experimental Station, Manikganj.

* values in columns followed by the same letter are not significantly different, P ≤ 0.05, LSD

Table 3: Effect of location on quality of jute seed

Location Name	1000-seed weight (g)	Germination percent	Field Emergence percent
JRSS	2.20a*	84.79b	79.62b
JAES	1.88b	89.83a	83.14a
%CV	5.45	8.63	8.73
LSD	0.12	3.30	3.11

Note: JRSS: Jute Research Sub-Station, Jashore; JAES: Jute Agriculture Experimental Station, Manikganj.

* values in columns followed by the same letter are not significantly different, P ≤ 0.05, LSD.

3.2 Effect of biochar and fertilizer on jute growth and yield contributing characters

Recommended dose of fertilizer (RDF), biochar and combination of RDF and biochar had significant effect on jute vegetative growth and yield contributing characters (Table 4). Results showed that treatment T₂

(RDF) and T₇ (RDF 75% + 25% Biochar@5.0tonha-1) increased plant height significantly whereas treatment T₃ (T₃=Biochar@3.0tonha-1) and T₁₄ (RDF 25% + 75% Biochar@8.0tonha-1) showed reduction in plant height among all treatments including control (T₁) (Table 4). In case of plant base diameter, expanded plant diameter was observed in three treatments (T₂, T₁₁ and T₁₂) however, lower plant base diameter was observed in two treatments T₃, T₁₄. Branches per plant were increased after application of RDF 25% + 75% Biochar@3.0tonha-1 (T₁₂) but most of the treatments negatively affected in increasing branches of jute.

Application of treatments showed negative effect on number of pods per plant and similarly pod length was not increased after application of either sole RDF and biochar or combinations of RDF with biochar (Table 4). However, pod diameter was increased (5.2 mm) by the treatment T₇ (RDF 75% + 25% Biochar@5.0tonha-1) compare to rest of the treatments. Seed yield was highest in T₆ and lowest in T₁₄ compare to other treatments along with control (T₁). Number of seed per pod was negatively affected by the treatments. It was quite interesting that plant population per plot

had no effect by the treatments (Table 4). From the above results it can be said that jute vegetative growth affected by different treatments were not the related to the jute seed yield. From these results it can be said that

single treatment is not enough to contribute the vegetative growth of jute and seed production.

Table 4: Effect of biochar treatments on yield and yield contributing characters of jute seed

Treatments	Plant height (cm)	Base Diameter (mm)	Plant population / plot	Branches / plant	Pod / plant	Pod length (cm)	Pod Diameter (mm)	No. of seed / pod	Seed yield / plant (g)
1	145.52bc*	7.18ab	159.3a	3.07ab	15.78a	6.93 a	4.82c	191.90a	2.91cd
2	163.50a	7.44a	161.67a	3.23ab	16.52a	6.28b	4.98abc	171.03b	3.45abc
3	143.22c	6.42b	187.17a	2.83 b	14.35ab	6.35b	5.09abc	179.07ab	2.92cd
4	149.95abc	6.99ab	168.50a	2.75b	14.53ab	6.66ab	4.98abc	179.53ab	3.10bcd
5	157.90abc	6.90ab	185.67a	3.08ab	15.97a	6.29b	4.88bc	179.05ab	2.89cd
6	157.25abc	7.04ab	166.50a	2.93 b	15.65ab	6.67ab	4.98abc	170.27b	3.98a
7	163.83a	7.35ab	170.00 a	2.98ab	15.82 a	6.41b	5.20a	184.75ab	3.53abc
8	152.75abc	6.95ab	158.17a	3.25ab	17.13a	6.32b	5.04abc	165.93b	3.80ab
9	158.35abc	6.90ab	158.67a	3.03ab	15.50ab	6.48ab	4.99abc	179.68ab	3.26abcd
10	160.18abc	7.00ab	162.00a	3.05ab	16.45a	6.33 b	5.14ab	169.25b	3.27abcd
11	159.60abc	7.49a	167.33a	2.98ab	15.05ab	6.51ab	5.06abc	170.58b	3.25abcd
12	161.92ab	7.47a	171.50a	3.48 a	16.05a	6.42b	4.97abc	170.05b	3.54abc
13	157.97abc	7.25ab	167.67a	3.07ab	16.62a	6.39b	4.91bc	165.02b	3.43abc
14	144.07c	6.38b	168.67a	2.77b	12.28 b	6.36b	4.98abc	171.53b	2.61d
%CV	9.69	11.90	11.97	14.79	19.24	6.21	4.68	9.87	19.75
LSD	17.44	0.97	32.27	0.52	3.47	0.46	0.27	19.99	0.75

values in columns followed by the same letter are not significantly different, P≤ 0.05, LSD.

3.3 Effect of biochar and fertilizer on quality of jute seed

Seed quality of jute was affected by the application of fertilizer and biochar (Table 5). Thousand seeds weight was positively affected by three treatments (T6, T7 and T10). However, T5 treatment reduced seed weight compare to the rest of the treatments and even less to the control treatment (T1). Results showed that application of RDF and biochar has no effect on seed germination. It was also found that treatments T4, T5, T7 and T9 affected negatively in field emergence percent and these were similar with the control treatment (T1). Treatment T14 (RDF 25% + 75% Biochar@8.0tonha-1) alone showed the positive effect of field emergence and the rest treatments showed the intermediate effect. These results indicate that seed weight and seed quality of jute are not reliant on the manure or fertilizer status of the growing field.

Table 5: Effect of biochar treatments on quality of jute seed

Treatments	1000 seed weight (g)	Germination percent	Field Emergence percent
1	1.98bcd*	85.33a	78.00b
2	2.09ab	91.83a	85.17ab
3	2.01abcd	88.83a	83.33ab
4	1.96cd	84.17a	78.17b
5	1.94d	85.33a	78.33b
6	2.13a	86.33a	81.00ab
7	2.12a	84.17a	78.17b
8	2.08abc	86.00a	79.67ab
9	1.98bcd	85.17a	79.00b
10	2.12a	86.00a	85.17ab
11	2.00abcd	90.50a	80.17ab
12	2.09ab	88.50a	84.67ab
13	2.05abcd	92.17a	82.83ab
14	1.98bcd	88.00a	87.83a
%CV	5.46	8.63	8.72
LSD	0.13	8.73	8.23

* values in columns followed by the same letter are not significantly different, P≤ 0.05, LSD.

3.4 Interaction effect of location and treatments on jute growth and yield contributing characters

The highest plant height 250.7 cm and 268.7 cm was found from the interaction L2 × T12 and L2 × T7, respectively; all treatments in location 1 (L1) showed the lowest plant height (Table 6). In case of plant base diameter, highest result (10.2 mm) was found in L2 × T12 and the lowest (4.4 mm) was in L1 × T14. Plant population per plot was not affected by the interaction of locations and treatments (Table 6). Branches per plant were higher in L2 × T12 and lower was in L1 × T4. Remaining interactions showed the intermediate result for branches per plant. Jute plant contain more pods in location 2 (L2) compare to the location 1 (L1) with interaction of all treatments. It was quite interesting that pod length was positively affected by location 1 (L1) compare to location 2 (L2). The highest pod length was found in L1 × T1 and L1 × T6 whereas lowest length was observed in L2 × T3.

Pod diameter was significantly, positively increased in all interaction except L1 × T1 and the highest diameter was found in L2 × T7. Number of seed per pod was higher (200) in treatment combination L2 × T1 and lower in two treatments L1 × T8 and L2 × T13. Higher seed weight per plant was higher in location 1 (L1) with T6 treatment and lower in location 1 (L1) with control (T1). Remaining interaction showed the intermediate result. It was also observed that treatment combination L2 × T12 showed the positive effect on plant vegetative growth compare to the other treatment combination. From these results it could be concluded that location affect significantly for growth and seed production of jute plant.

3.5 Interaction effect of location and treatments on quality of jute seed

Combination of interaction showed significant effect on thousand seed weight (Table 7). Highest seed weight was observed in the treatment combination L1 × T10 and lower weight was observed in location 2 (L2) with the most of the treatments. Higher seed germination percent (99.0) was found in two treatments L2 × T2 and L2 × T13, respectively. Treatment combination L1 × T6, L1 × T10, L2 × T4 and L2 × T7 showed the lower seed germination percentage (Table 7). Most of the treatment combination showed the negative effect on field emergence percentage; only the combination L2 × T2 shoed the positive effect. In addition, L2 × T2 showed positive effect on both seed germination and field percentage (Table 7). It was also observed that L1 × T10 had positive effect on seed weight however, seed germination and field emergence percentage was negative. These results pointed that location along with different treatment had no interaction effect on seed quality.

Table 6: Location × treatment interaction effect on yield and yield contributing characters of jute seed

Interaction	Plant height (cm)	Base Diameter (mm)	Plant population / plot	Branches / plant	Pod / plant	Pod length (cm)	Pod Diameter (mm)	No. of seed / pod	Seed yield / plant (g)
L ₁ × T ₁	72.70 e*	5.16e	144.00a	2.73efgh	10.47 e	7.18 a	4.75e	183.80abcd	1.93h
L ₁ × T ₂	84.67e	5.20ef	164.33a	2.83defgh	10.67e	6.60abcde	4.88bcde	177.73abcd	3.65abcde
L ₁ × T ₃	74.10e	4.75ef	189.00a	2.43gh	8.37e	6.77 ab	4.97 bcde	174.47abcd	2.60efgh
L ₁ × T ₄	72.23e	4.63ef	181.67a	2.27 h	8.53e	6.65abcd	4.92bcde	180.73abcd	2.98cdefg
L ₁ × T ₅	73.8e	4.52ef	183.67a	2.43gh	8.53e	6.55 abcdef	4.90 bcde	169.43bcd	2.30gh
L ₁ × T ₆	82.83e	5.83e	168.0 a	2.93cdefgh	12.33de	7.17a	4.90bcde	179.20abcd	4.56a
L ₁ × T ₇	79.00e	5.40ef	177.00a	2.57fgh	9.43e	6.78ab	4.90bcde	180.83abcd	3.62abcde
L ₁ × T ₈	76.50e	5.43ef	157.67a	3.27bcdef	11.83de	6.33bcdef	5.00bcde	159.53d	3.71abcd
L ₁ × T ₉	78.37e	5.08ef	160.33a	2.80defgh	9.633e	6.53abcdef	5.18 abc	167.36bcd	3.30bcdefg
L ₁ × T ₁₀	75.37e	5.12 ef	156.67a	2.47 gh	9.60e	6.42bcdef	5.02 bcde	168.17bcd	3.65abcde
L ₁ × T ₁₁	81.87e	5.27ef	159.67a	2.67efgh	9.63e	6.60abcde	4.783de	175.17abcd	2.84defgh
L ₁ × T ₁₂	73.17e	4.72ef	172.67 a	2.63 fgh	8.07e	6.20 bcdef	4.88bcde	163.43cd	2.98cdefgh
L ₁ × T ₁₃	74.93e	4.95ef	171.33a	2.60fgh	10.00e	6.50bcdef	4.87bcde	170.70bcd	2.96cdefgh
L ₁ × T ₁₄	66.13e	4.40f	160.00a	2.40gh	8.13e	6.68abc	5.18 abc	168.73bcd	3.08bcdefg
L ₂ × T ₁	218.33cd	9.19abcd	174.67a	3.40bcde	21.10abc	6.67 abcd	4.90bcde	200.00a	2.34fgh
L ₂ × T ₂	242.33abc	9.68ab	159.00a	3.63abc	22.37ab	5.95ef	5.07bcde	164.33bcd	3.91abc
L ₂ × T ₃	212.33d	8.08d	185.33a	3.23 bcdef	20.33abc	5.93f	5.21 ab	183.67abcd	3.26bcdefg
L ₂ × T ₄	227.67abcd	9.35abcd	155.33a	3.23 bcdef	20.53abc	6.67abcd	5.04bcde	178.33abcd	3.25bcdefg
L ₂ × T ₅	242.00abc	9.28abcd	187.67 a	3.73 ab	23.40ab	6.03def	4.85bcde	188.67abc	3.22bcdefg
L ₂ × T ₆	231.67abcd	8.25cd	165.00a	2.93cdefgh	18.97bc	6.18bcdef	5.05bcde	161.33cd	3.49bcde
L ₂ × T ₇	248.67a	9.31abcd	163.00a	3.40bcde	22.20ab	6.03def	5.49a	188.67abc	3.39bcdef
L ₂ × T ₈	229.00abcd	8.47bcd	158.67a	3.23bcdef	22.43ab	6.31bcdef	5.07bcde	172.33abcd	3.44bcde
L ₂ × T ₉	238.33abc	8.71bcd	157.00a	3.27bcdef	21.37ab	6.43bcdef	5.18 abc	192.00ab	3.88abcd
L ₂ × T ₁₀	245.00ab	8.89abcd	167.33a	3.63abc	23.30 ab	6.23bcdef	5.09bcde	170.33bcd	3.69abcd
L ₂ × T ₁₁	237.33abc	9.72ab	175.00a	3.30bcdef	20.47abc	6.42 bcdef	5.08bcde	166.00bcd	3.53abcde
L ₂ × T ₁₂	250.67a	10.22a	170.33 a	4.33a	24.03a	6.63abcd	5.15 abcd	176.67abcd	4.12ab
L ₂ × T ₁₃	241.00abc	9.55abc	164.00a	3.53bcd	23.23ab	6.29bcdef	4.93bcde	159.33d	3.78abcd
L ₂ × T ₁₄	222.00bcd	8.37bcd	177.33 a	3.13bcdefg	16.43cd	6.03 cdef	5.09bcde	174.33abcd	2.88cdefgh
%CV	9.68	11.92	11.98	14.79	19.23	6.21	4.68	9.87	19.75
LSD	24.66	1.38	45.63	0.74	4.90	0.66	0.38	28.27	1.06

L₁ = Jute Research Sub-Station, Monirumpur, Jashore; L₂ = Jute Agriculture Experimental Station, Manikganj.

* values in columns followed by the same letter are not significantly different, P ≤ 0.05, LSD.

Table 7: Location × treatment interaction effect on quality of jute seed

Location × treatment Interaction	1000-Seed weight	Germination percent	Field Emergence percent
L ₁ × T ₁	2.20bcd*	84.33bc	77.00d
L ₁ × T ₂	2.33abc	84.67bc	78.00d
L ₁ × T ₃	2.12de	84.67bc	79.67cd
L ₁ × T ₄	2.11de	86.00bc	80.00cd
L ₁ × T ₅	2.10de	86.00bc	78.33d
L ₁ × T ₆	2.35ab	82.00c	78.00d
L ₁ × T ₇	2.19bcd	86.00bc	80.67bcd
L ₁ × T ₈	2.21abcd	84.33bc	79.33cd
L ₁ × T ₉	2.16cd	84.67bc	79.00cd
L ₁ × T ₁₀	2.39a	81.33c	76.67d
L ₁ × T ₁₁	2.19bcd	84.67bc	79.33cd
L ₁ × T ₁₂	2.32abc	86.00bc	81.67abcd
L ₁ × T ₁₃	2.08def	85.33bc	83.33abcd
L ₁ × T ₁₄	2.11de	87.00abc	76.67d
L ₂ × T ₁	1.78h	86.33bc	79.00cd
L ₂ × T ₂	1.86gh	99.00a	92.33a
L ₂ × T ₃	1.90fgh	93.00abc	87.00abcd
L ₂ × T ₄	1.81h	82.33c	76.33d
L ₂ × T ₅	1.78h	84.67bc	78.33d
L ₂ × T ₆	1.91fgh	90.67abc	75.67d
L ₂ × T ₇	2.05def	82.33c	80.00cd
L ₂ × T ₈	1.96efgh	87.67abc	79.00cd
L ₂ × T ₉	1.81h	85.67bc	76.33d
L ₂ × T ₁₀	1.86gh	90.67abc	83.67abcd
L ₂ × T ₁₁	1.82h	96.33ab	90.00abc
L ₂ × T ₁₂	1.86gh	91.00abc	84.00abcd
L ₂ × T ₁₃	2.03defg	99.00a	92.00ab
L ₂ × T ₁₄	1.84h	90.67abc	82.67abcd
%CV	5.45	8.63	8.73
LSD	0.18	12.34	11.64

L₁ = Jute Research Sub-Station, Monirumpur, Jashore; L₂ = Jute Agriculture Experimental Station, Manikganj.

* values in columns followed by the same letter are not significantly different, P ≤ 0.05, LSD.

3.6 Correlation coefficient analysis of vegetative growth and quality of seed of jute

Statistical analyses were carried out to understand the associations among vegetative growth and seed quality of jute. Analysis revealed that significant, and positive correlation was found for plant height (PH) with base diameter (BD), branches per plant (BP), plant population per plot (PPP), pod diameter (PD) and percentage of seed germination (PGR). However, pod length (PL), thousand seed weight (TSW) and seed weight per plant (SWP) was significantly, and negatively correlated with plant height (Table 8). Plant base diameter (BD) had strong positive relation with branches per plant (BP), plant population per plot (PPP) and significant negative correlation with thousand seed weight (TSW) and seed weight per plant (SWP) (Table 8). It was also observed that vegetative growth had negative correlation with jute seed yield and seed quality. In addition, seed weight showed negative relation with seed germination (PGR) and field emergence (FE).

4. DISCUSSION

In agricultural sector, deterioration and impotence of soil are common obstacle for crop production (Chan and Xu, 2009). Increasing number of studies focused on the application of biochar for the improvement of soil properties for proper production of crop. Biochar improve soil structure to increase water holding capacity and nitrogen availability for the crop (Bruun et al., 2012; Laird et al., 2010). Crop production is highly depended on soil type, temperature, annual rainfall etc. (Mall et al., 2017; Masikati et al., 2019). Bangladesh has been divided in thirty agro-ecological zones (AEZ) based on the physiography, soils, land levels in relation to flooding and agro-climatology. It has been reported that crop productivity varies in different AEZs due to several phenomena (Quddus, 2009). In our research we also observed variation in vegetative growth and seed production of jute (Table 2 and Table 3).

Jute Agriculture Experimental Station, Manikganj (JAES) is situated in AEZ-8 and Jute Research Sub-Station, Monirampur, Jashore (JRSS) is under the AEZ-11 (http://en.banglapedia.org/index.php?title=Agroecological_Zone). The silt-loam soil of JAES might play significant role not only to improve growth and yield but also quality of seed of jute variety BJRI tossa-8. Similar report was found in the cultivation of edible *Amaranthus tricolor* lines in Japan where production of *Amaranthus tricolor* was higher in grey soil (Oshiro et al., 2016).

Plant requires various types of soil nutrients like N, P and K for their proper growth but those nutrients decrease over time in the soil (Rawat et al., 2019). To fulfill the required N, P and K in the soil, huge amount of chemical fertilizer is used however, plant can uptake a small amount from the soil and rest are converted into insoluble forms leading to reducing soil fertility, soil degradation, soil compaction and loss of soil carbon (Hariparasad and Dayananda, 2013; Lin et al., 2019). Biochar is a soil amendment agent which has unique physical and chemical properties that can promote crop growth and development as well as crop yield (Gwenzi et al., 2016; Hammer et al., 2014; Olmo et al., 2016). In this research it was

found that most of the plant growth parameters were negatively affected by biochar application (Table 4).

However, pod diameter and seed production of each plant was somehow positively affected. In addition, plant population and pods per plant was same in all treatments including control (Table 4). These results indicated that application of biochar alone or combination with fertilizer may not provide sufficient nutrients for proper plant growth. Crops respond to biochar in various ways and sometimes may not give the expected potential yield directly but improve the soil health directly (Brandstaka et al., 2010; Chan et al., 2008; Deenik et al., 2010; Jien and Wang, 2013). Plant growth is highly depended on the soil type, cultivated crops, biochar source and cultivation techniques (Jeffery et al., 2015; Oshiro et al., 2016). In addition, crop yield is highly related to the plant population and growth status of specific crop (Haarhoff and Swanepoel, 2018; Jolliffe et al., 1990).

Crop production and seed quality are the fundamental parameters reflecting the efficacy of plant production (Salentnik et al., 2019). Seed weight, germination percentage and field emergence of seeds provide the seed quality (Bekele et al., 2019). Reports showed that application of biochar increase seed germination capacity of potato and wheat (Bamberg et al., 1986; Van Zwieten et al., 2010). However, maize seed germination and was not significantly affected by the application of biochar (Free et al., 2010). It has been reported that biochar contains unwanted compounds as well as small to high concentration of nutrients that may inhibit seed germination (Garnett et al., 2004; Gaskin et al., 2008; Hille and den Quden, 2005). Seed weight of jute in our study positively affected by the biochar application with inorganic fertilizer indicating the proper development of seed through soil treated with biochar (Table 5).

Percentage of seed germination in laboratory condition was not affect by biochar application but field emergence percentage was highly affected by the seeds grown with biochar. Biochar might alter the organic mineralization which may be linked to the nitrogen mineralization and change in nutrient status which may affect both seed germination in field. Similar mechanism was reported by the experiments (Murphy et al., 2003; Steiner et al., 2008). Plant growth often affected by the temperature, soil type, annual rainfall of a particular area and understanding how plant interact with environmental factors is extremely important (Fourcaud et al., 2008; Mall et al., 2017). Jute can be grown in various soil but soil pH ranging between 5.0-8.6 is optimum for best production.

JAES is under AEZ-8 having good soil organic matter and JRSS in under AEZ-11 having low soil fertility condition. Interaction between location and different treatments found the lower vegetative growth in location 1(L1) compare to the location 2 (L2). However, plant population of plant was not affected by the different interactions (Table 6). These results suggesting the importance of location for jute cultivation. Our prediction was supported by the study where location was reported to be influenced by the environmental factors (Baker and Capel, 2011). Field emergence percentage also supporting our observation of soil and environmental condition leading to jute growth and germination in the field level (Table 7).

Table 8: Correlation coefficients of vegetative growth and seed quality.

	PH	BD	PPP	BP	PL	PD	NSP	TSW	SWP	PGR	FE	
PH	1.00											
BD	0.94**	1.00										
PPP	0.03	-0.06**	1.00									
BP	0.67**	0.79**	-0.14	1.00								
PL	-0.37**	-0.23**	-0.06	-0.13	1.00							
PD	0.37**	0.32**	0.07	0.23**	0.30	1.00						
NSP	0.11	0.17**	0.08	0.14	0.15	0.37**	1.00					
TSW	-0.74**	-0.67**	-0.15	-0.43**	-0.62**	0.31**	-0.15**	1.00				
SWP	-0.90**	-0.82**	0.03	-0.53**	-0.80**	0.42**	-0.33**	-0.08**	0.74	1.00		
PGR	0.29**	0.30**	0.15	0.17	0.19	-0.18	-0.07**	-0.11**	-0.34	-0.30	1.00	
FE	0.21	0.21	0.17	0.10	0.12	-0.20	-0.10	-0.13**	-0.28	-0.23	0.97	1.00

PH- Plant height; BD- Base diameter; PPP- Plant population/ plot; BP- Branches/ plant; PP- Pod/ plant; PL- Pod length; PD- Pod diameter; NSP- No. of seed/ pod; TSW- 1000 seed weight; SWP- Seed weight/ plant; PGR- % germination rate; FE- Field emergence.

**- Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

Correlation coefficient indicates the strong relationship between to variables (Ratner, 2009). For optimum production of a plant, leaf area, plant height and total plant biomass are important because these involve in photosynthesis leading to yields (Arif et al., 2017). In this study plant growth parameters were significantly, and negatively correlated with yield contributing characters and finally yield (Table 8). However, plant height was positively correlated with base diameter, branches per plant and population per plot. These results clearly indicated that changes of plant growth parameter may change the yield and yield contributing parameter.

5.CONCLUSION

Jute plant need numbers of nutrients for its growth and proper development. Although applying of inorganic fertilizers increase crop yield but deteriorate soil health as well resulting decrease of crop yield. Biochar is a charcoal which is used to improve soil health and creates a scope to release nutrients slowly. In this present study the combination of inorganic fertilizer and biochar was applied in various combination. Application of biochar alone had not significant effect on vegetative growth of jute however, some combination with inorganic fertilizer showed the positive effect. Treatment T2 increased plant height, base diameter and pod/plant. In addition, treatment T6 gave the highest seed yield per plant. Seed quality was significantly affected by the interaction of treatment T2 with location L2.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

SNI, MLR, MZT and MAS designed the study. SNI, MLR, BM, MMK, AS and MZT conducted field works and collected data. SNI analyzed the data. SNI, MLR, MZT and MAS worked on the manuscript.

REFERENCES

- Ali, M.S., Hoque, M.M., Alim, M.A., Islam, M.M., 2019. A nutrient combination that can affect yield of *Olitorius jute*. *Plant*, 7 (3), Pp. 42-46.
- Al-Snafi, A.E., 2016. The contents and pharmacological importance of *Corchorus capsularis*- a review. *IOSR Journal of Pharmacy*, 6 (6), Pp. 58-63.
- Anonymous., 2013. *Monthly Economic Trends*, October 2013. Statistics Department, Bangladesh Bank, Dhaka, Pp. 27.
- Arif, M., Ilyas, M., Riaz, M., Ali, K., Shah, K., Haq, I.U., Fahad, S., 2017. Biochar improves phosphorus use efficacy of organic-inorganic fertilizer, maize-wheat productivity and soil quality in low fertility alkaline soil. *Field Crops Research*, 214, Pp. 25-37.
- Asai, H., Samson, B.K., Stephan, H.M., Songyikhangsuthor, K., Homma, K., Kiyono, Y., Inoue, Y., Shiraiwa, T., Horie, T., 2009. Biochar amendment techniques for upland rice production in Northern Laos 1. Soil physical properties, leaf SPAD and grain yield. *Field Crop Research*, 111 (1-2), Pp. 81-84.
- Bamberg, J.B., Hanneman Jr, R.E., Towill, L.E., 1986. Use of activated charcoal to enhance the germination of botanical seeds of potato. *American Potato Journal*, 63, Pp. 181-189.
- Baker, N.T., Capel, P.D., 2011. Environmental factors that influence the location of crop agriculture in the conterminous United States: U.S. Geological Survey Scientific Investigations Report, Pp.72.
- Bekele, N., Tesso, B., Fikre, A., 2019. Assessment of seed quality parameters in different seed sources of chickpea (*Cicer arietinum* (L.)). *African Journal of Agricultural Research*, 14 (33), Pp. 1649-1658.
- Brandstaka, T., Helenius, J., Hovi, J., Kivela, J., Koppelmaki, K., Simojoki, A., Soinne, H., Tammeorg, P., 2010. Biochar filter: use of biochar in agriculture as soil conditioner. University of Helsinki, Helsinki, Finland.
- Bruun, E.W., Ambus, P., Egsgaard, H., Hauggaard-Nielsen, H., 2012. Effects of slow and fast pyrolysis biochar on soil C and N turnover dynamics. *Soil Biology and Biochemistry*, 46, Pp. 73-9.
- Chan, K.Y., Zwieten, L.V., Meszaros, I., Downie, A., Joseph, S., 2007. Agronomic values of green waste biochar as a soil amendment. *Australian Journal of Soil Research*, 45 (8), Pp. 629-634.
- Chan, K.Y., Xu, Z., 2009. Biochar: Nutrient properties and their enhancement. In: Lehmann, J. Joseph, S. (Eds.), *Biochar for Environmental Management: Science and Technology*. Earthscan, London, Pp. 67-84.
- Chan, K., Van Zwieten, L., Meszaros, I., Downie, A., Joseph, S., 2008. Agronomic values of green waste biochar as a soil amendment. *Soil Research*, 45, Pp. 629-34.
- Chowdhury, M.A.H., Hassan, M.S., 2013. *Hand book of agricultural technology*. Bangladesh Agricultural Research Council, Dhaka, Bangladesh.
- Deenik, J.L., McClellan, T., Uehara, G., Antal, M.J., Campbell, S., 2010. Charcoal volatile matter content influences plant growth and soil nitrogen transformations. *Soil Science Society of America Journal*, 74 (4), Pp. 1259-1270.
- FAO (Food and Agriculture Organization of the United Nations), 2014. *Statistical bulletin-2014*.
- Fourcaud, T., Zhang, X., Stokes, A., Lambers, H., Korner, C., 2008. Plant growth modelling and applications: the increasing importance of plant architecture in growth models. *Annals of Botany*, 101 (8), Pp. 1053-1063.
- Free, H.F., McGill, C.R., Rowarth, J.S., Hedley, M.J., 2010. The effect of biochars on maize (*Zea mays*) germination. *New Zealand Journal of Agronomy Research*, 53 (1), Pp. 1-4.
- Garnett, E.L., Jonsson, M., Dighton, J., Murnen, K., 2004. Control of pitch pine seed germination and initial growth exerted by leaf litters and polyphenolic compounds. *Biology and Fertility of Soils*, 40, Pp. 421-426.
- Gaskin, J.W., Steiner, C., Harris, K., Das, K.C., Bibens, B., 2008. Effect of low-temperature pyrolysis conditions on biochar for agricultural use. *Transaction of ASABE*, 51 (6), Pp. 2061-2069.
- Gomez, K.A., Gomez, A.A., 1984. *Statistical procedures for agricultural research*. 2nd ed. John Wiley Sons, New York.
- Gwenzi, W., Muzava, M., Mapanda, F. Tauro, T.P., 2016. Comparative short-term effects of sewage sludge and its biochar on soil properties, maize growth and uptake of nutrients on a tropical clay soil in Zimbabwe. *Journal of Integrative Agriculture*, 15 (6), Pp. 1395-1406.
- Hammer, E.C., Balogh-Brunstad, Z., Jakobsen, I., Olsson, P.A., Stipp, S.L.S., Rillig, M.C., 2013. A mycorrhizal fungus grows on biochar and captures phosphorus from its surface. *Soil Biology & Biochemistry*, 77, Pp. 252-260.
- Hariparasad, N.Y., Dayananda, H.S., 2013. Environmental impact due to agricultural runoff containing metals- a review. *International Journal of Scientific and Research Publication*, 3 (5), Pp. 1-6.

- Haarhoff, S.J., Swanepoel, P.A., 2018. Plant population and maize grain yield: a global systematic review of rainfed trials. *Crop Science*, 58, Pp. 1819-1829.
- Hille, M., den Quden, J., 2005. Charcoal and activated carbon as adsorbate to phytotoxic compounds-a comparative study. *Oikos*, 108 (1), Pp. 202-207.
- Hossain, M.B., Uddin, M.N., Alam, M.J., Ali, M.Y., Rahman, M.R., 2017. Economic performance of jute cultivation at farm level in some selected areas of Bangladesh. *Journal of Experimental Bioscience*, 5 (1), Pp. 97-104.
- Hussain, M., Farooq, M., Nawaz, A., Al-Sadi, A.M., Solaiman, Z.M., Alghamdi, S.S., Ammara, U., Ok, Y.S. Siddique, K.H.M., 2017. Biochar for crop production: potential benefits and risks. *Journals of Soils and Sediments*, 17, Pp. 685-716.
- Islam, M.M., Ali, M.S., 2017. Economic importance of jute in Bangladesh: production, research achievements and diversification. *International Journal of Economic Theory and Application*, 4 (6), Pp. 45-57.
- Islam, M.M., Rahman, M., 2008. In: *Hand book on agricultural technologies of jute, kenaf and mesta crops*. Bangladesh Jute Research Institute, Manik Mia Avenue, Dhaka-1207, Bangladesh.
- Islam, M.S., 2007. Management of some jute diseases. MS Thesis. Bangladesh Agricultural University, Mymensingh, Bangladesh.
- Jeffery, S., Abalos, D., Spokas, K., Verheijen, F.G.A., 2015. Biochar effect on crop yield. *Biochar for environmental management, Science, Technology and Implementation*. 2nd edition, Routledge.
- Jien, S.H., Wang, C.S., 2013. Effects of biochar on soil properties and erosion potential in a highly weathered soil. *CATENA*, 110, Pp. 225-233.
- Jolliffe, P.A., Tarimo, A.J.P., Eaton, G.W., 1990. Plant growth analysis: growth and yield component responses to population density in forage maize. *Annals of Botany*, 6 (2), Pp. 139-147.
- Laird, D.A., Fleming, P.D., Davis, D.D., Horton, R., Wang, B., Karlen, D.L., 2010. Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma* in press: Geoderma. doi: 10.1016/j.geoderma.2010.1005.1013.
- Lehmann, J., Rondon, M., 2006. Bio-char soil management on highly weathered soils in the humid tropics. In Uphoff, N. (ed.) *Biological Approaches to Sustainable Soil Systems*, CRC Press, Boca Raton, FL, USA, Pp. 517-530.
- Lin, W., Lin, M., Zhou, H., Wu, H., Li, Z., Lin, W., 2019. The effects of chemical and organic fertilizer usage on rhizosphere soil in the tea orchards. *PLoS ONE*, 14 (5), Pp. e0217018.
- Mall, R.K., Gupta, A., Sonkar, G., 2017. Effect of climate change on agricultural crops. In *Current developments in biotechnology and bioengineering, crop modification, nutrition, and food production*. Pp. 23-46.
- Masikati, P., Descheemaeker, K., Crespo, O., 2019. Understanding the role of soils and management on crops in the face of climate uncertainty in Zimbabwe: a sensitivity analysis. In: Rosenstock T., Nowak A., Girvetz E. (Eds), *The Climate-Smart Agriculture Papers*. Springer, Cham, Pp.49-64.
- Mollah, M.A.F., Tareq, M.Z., Bashar, K.K., Hoque, A.B.M.Z., Karim, M.M., Rafiq, M.Z.A., 2020. Antioxidant properties of BJRI vegetable mesta-1 (*Hibiscus sabdariffa* L.). *Plant Science Today*, 7 (2), Pp. 154-156.
- Murphy, D.V., Recous, S., A.Stockdale, E., Fillery, I.R.P., Jensen, L.S., Hatch, D.J., Goulding, K.W.T., 2003. Gross nitrogen fluxes in soil: theory, measurement and application of 15N pool dilution techniques. *Advance in Agronomy*, 79, Pp. 69-119.
- Nair, V.D., Nair, P.K.R., Dari, B., Freitas, A. M., Chatterjee, N., Pinheiro, F, M., 2017. Biochar in the agroecosystem-climate-change-sustainability nexus. *Frontiers in Plant Science*, 8, Pp. 2501.
- Olmo, M., Villar, R., Salazar, P., Alburquerque, J.A., 2016. Changes in soil nutrient availability explain biochar's impact on wheat root development. *Plant & Soil*, 399 (1), Pp. 1-11.
- Oshiro, M., Hossain, M.A., Nakamura, I., Akamine, H., Tamaki, M., Bhowmik, P.C., Nose, A., 2016. Effect of soil types and fertilizer on growth, yield and quality of edible *Amaranthus tricolor* lines in Okinawa, Japan. *Plant Production Science*, 19 (1), Pp. 61-72.
- Quddus, M.A., 2009. Crop production growth in different agro-ecological zones of Bangladesh. *Journal of Bangladesh Agricultural University*, 7 (2), Pp. 351-360.
- Rashid, M.M., Khan, M.M.R., Hossain, M.A., Hossain, M.M., 2007. Management of seed borne fungi of jute in Mymensingh region. *Bangladesh Journal of Crop Science*, 18, Pp. 209-214.
- Ratner, B., 2009. The correlation coefficient; its value range between +1/-1, or do they? *Journal of Targeting, Measurement and Analysis for Marketing*, 17, Pp. 139-142.
- Rawat, J., Saxena, J., Sanwal, P., 2019. Biochar: a sustainable approach for improving plant growth and soil properties. *An Imperative amendment for soil and the environment*.
- Salentnik, B., Bajcar, M., Zagula, G., Salentnik, A., Tarapatsky, M., Puchalski, C., 2019. Biochar as a stimulator for germination capacity in seeds of Virginia mallow (*Sida hermaphrodita* (L.) Rsuby). *Applied Sciences*, 9 (16), Pp. 3213.
- Sikder, F.S., Saha, C.K., Rahman, M., Alam, A.K.N.M., Haque, S., 2008. Jute production in Bangladesh- an overview. Abstracts of papers, International symposium on jute and allied fibres production, utilization and marketing. National library, Kolkata, India, Pp. 9-12.
- Srinivasarao, Y., Gopinath, K.A., Venkatesh, G., Dubey, A.K., Wakudar, H., Purakayastha, T.J., Pathak, H., Jha, P., Lakaria, B.L., Rajkhowa, D.J., Mandal, S., Jeyaraman, S., Venkateswarlu, B., Sikka, A.K., 2013. Use of biochar for soil health enhancement and greenhouse gas mitigation in India: potential and constraints. *Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh*, Pp. 51.
- Steiner, C.K., Das, C., Garcia, M., Forster, B., Zech, W., 2008. Charcoal and smoke extract stimulate the soil microbial community in a highly weathered xanthic Ferralsol. *Pedobiologia*, 51 (5-6), Pp. 359-366.
- Tareq, M.Z., Bashar, K.K., Amin, M.R., Sarker, M.D.H., Moniruzzaman, M., Sarker, M.S.A., Islam, M.S., 2019. Nutritional composition of some jute genotypes as vegetables. *International Journal of Vegetable Science*, DOI 10.1080/19315260.2019.1658686.
- Toma, K., 2017. Effect of biochar on growth and yield of mung bean (BARIMung-6). MS thesis. Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.
- Van Zwieten L., Kimber, S., Morris, S. Chan, K.Y., Downie, A., Rust, J., Joseph, S., Cowie, A., 2010. Effects of biochar from slow pyrolysis of paper mill waste on agronomic performance and soil fertility. *Plant Soil*, 27, Pp. 235-246.
- Verheijen, F.G.A., Jeffery, S., Bastos, A.C., Velde, V.D., Diapas, M.I., 2009. Biochar application to soils: A critical scientific review of effects on soil properties, processes and functions. Luxembourg: Office for Official Publications of the European Communities. EUR 24099 EN. 61.
- Vinh, N., Hien, N., Anh, M., Lehmann, J., Joseph, S., 2014. Biochar treatment and its effects on rice and vegetable yields in mountainous areas of northern

Vietnam. *International Journal of Agricultural and Soil Science*, 2 (1), Pp. 5-13.

Yamato, M., Okimori, Y., Wibowo, I.F., Anshori, S., Ogawa, M., 2006. Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil Science and Plant Nutrition*, 52 (4), Pp. 489-495.

Yilangai, R.M., Manu, A., Pineau, W., Mailumo, S., Okeke-Agulu, K., 2014. The effect of biochar and crop veil on growth and yield of Tomato

(*Lycopersicon esculentus* Mill) in Jos, North central Nigeria. *Current Agriculture Research Journal*, 2 (1), Pp. 37-42.

Zhu, Q.H., Peng, X.H., Huang, T.Q., Xie, Z.B., Holden, N.M., 2014. Effect of biochar addition on maize growth and nitrogen use efficiency in acidic red soils. *Pedosphere*, 29 (2), Pp. 699-708.

Zhang, G., Qi, J., Xu, J., Niu, X., Zhang, Y., Tao, A., Zhang, L., Fang, P., Lin, L., 2013. Overexpression of UDP-glucose pyrophosphorylase gene could increase cellulose content in jute (*Corchorus capsularis* L.). *Biochemical and Biophysical Research Communications*, 442 (3-4), Pp. 153-158.

