Enhancing Bitter Gourd Production in Bangladesh's Coastal Saline Soil by Mulching and Fertilizing with Potassium

ABSTRACT

Salinity is a major constraint to higher crop production in the southern coastal soils of Bangladesh. To overcome this problem, a study was undertaken with the application of different mulch materials and potassium fertilizer doses during 2017-18 and 2018-19 at Barguna district of Bangladesh.The test crop was a bitter gourd. The experiments were laid out in a two-factor randomized complete block design with three replications. The first factor was different types of mulch material (M_1: no mulch, M_2: rice straw mulch, and M_3: polythene mulch), and the second factor was different rates of potassium (K) fertilizer (K_1: no K fertilizer, K_2: 100% recommended K fertilizer, and K_3: 150% recommended K fertilizer).The effect of mulch materials and potassium fertilizer doses recorded significantly higher yield, yield components, and nutrient uptake of bitter gourd in both the years over control treatment. In the case of mulching, the polythene mulch treatment had the best performance in all tested parameters, followed by rice straw mulch and no mulch treatment. The polythene mulch treatment resulted in a 136% and 198% higher yield over no mulch treatment in two years, respectively. Regarding the K effect, the 150% recommended K fertilizer gave the best performance, followed by the 100% recommended K fertilizer and control treatment. Application of 150% recommended K increased 39 and 68% higher yield over K control treatment in two years, respectively. The polythene mulch and/or 150% recommended K fertilizer gave the highest positive results among all the tested treatments. On the other hand, the use of polythene mulch and/or 150% recommended K fertilizer gave the lowest soil EC and exchangeable soil Na. Therefore, polythene mulch and/or 150% recommended K fertilizer could be a new package for increasing bitter gourd yield by reducing salinity in coastal saline soil of Bangladesh.

Key words: Mulching, Potassium fertilizer, Saline soil, bitter gourd yield and Bangladesh.

1. INTRODUCTION

Bangladesh is a country of agriculture, and more than 80% of the total population is directly or indirectly involved with agriculture. The total area of Bangladesh is 147,570 km^2. The coastal area covers about 20% of the country and over 30% of the net cultivable area [1]. Out of 2.86 million hectares of coastal and offshore land, about 1.056 million ha of arable land is affected by varying degrees of salinity [2].Soil salinity is a global issue threatening land productivity, and estimates predict that 50% of all arable land will become impacted by salinity by 2050 [21]. The major challenges facing this region are the threat of climate change, soil and water salinity, water logging, and resource (land and water) degradation [3]. These changes arenegatively impact onsoil fertility and crop productivity, which underpin the rural economy of coastal Bangladesh. On the other hand, the farmers of the coastal area mostly cultivate low-yield mono-crop local rice varieties and sometimes dry land crops in Rabi and Kharif-1 seasons like mungbean, sesame, bitter gourd, snake gourd, sweet gourd, etc. for their staple food and other requirements. But this is highly weather-dependent. Most of the farmers can't harvest their crops due to adverse climatic conditions, and finally, they financially lose. Now the challenge for Bangladesh is how best to adapt the farmers to cultivate more crops and increase crop production by reducing soil and water salinity problems in coastal regions. Polythene mulches reduce evaporation losses from the soil surface, accelerate crop development in cool climates by increasing soil temperature, and reduce salinity. Kumar *et al.* [4]reported that polythenemulch produces more yield by conserving more moisture. Salt tolerance is directly associated with potassium (K) contents because of its involvement in osmotic regulation and competition with sodium (Na). Therefore, the application of K in excess may facilitate maintaining a higher K^+:Na^+ ratio, which increases the tolerance capacity of crops to salinity [5]. Considering the above facts, using polythene mulch and optimum K fertilizer is suitable for reducing soil salinity. In view of the above scenario, the present study was conducted to determine the effects of polythene mulch and K fertilizer on crop yield in the coastal saline soils of Bangladesh.

2. MATERIALS AND METHODS

2.1 Experimental sites

The experiment was conducted in the Barguna district of Bangladesh. The experimental field was located at $22^0$37′ N latitude and $89^0$10′ E longitude at Ganges Tidal Floodplains (AEZ 13).

2.2 Climate

The experimental area is situated in the sub-tropical climatic zone and is characterized by heavy rainfall during the months of April-September (Kharif season) and scanty rainfall during the rest of the year. The Rabi season (October-March) is characterized by comparatively low temperatures and plenty of sunshine from November to February [2].

2.3 Crop and variety

The bitter gourd was used as a test crop, and the variety was Lal Teer Hybrid Karala Tia. It is a popular variety of bitter gourdin Bangladesh.

2.4 Treatment details

Factor A: types of mulch material (M_1:no mulch, M_2: rice straw mulch, and M_3: polythene mulch) and Factor B: rate of K fertilizer (K_1: noK fertilizer, K_2: 100% recommended K fertilizer, and K_3: 150% recommended K fertilizer). Therefore, nine treatment combinations were used in the experiment. The N, P, and K were applied at a recommended rate of 75, 30, and 50 kg ha^{-1}, respectively. Therefore, 100% and 150% recommended K mean 50 and 75 kg K ha^{-1}, respectively.

2.5 Experimental design

The experiments were laid out in a two-factor randomized complete block design with three replications.

2.6 Recording of plant and soil data

The yield and yield contributing parameters, such as primary stem length, number of leaves per primary stem, number of branches per plant, number of fruits per plant, fruit yield, and nutrient uptake of bitter gourd leaf were recorded following standard protocol. Post-harvest soil samples were analyzed for EC and exchangeable Na content. Soil EC was measured in 1:5 soil-water suspensions using an EC meter (HANNA EC 214) [6]. The exchangeable Na content was determined by the ammonium acetate (NH_4OAc) extraction method [7].

2.7 Economic analysis

Economic analysis was done following the principle of partial budget analysis [8].The marginal benefit-cost ratio (MBCR) is indicative of the superior treatments. The MBCR is the ratio of added benefit and added cost. To compare different treatments with control treatments, the following formula was used-

$$\text{MBCR} = \frac{\text{Gross return (tested treatments)} - \text{Gross return (control treatment)}}{\text{VC (tested treatments)} - \text{VC (control treatment)}}$$

$$= \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}}$$

Where, VC = Variable cost (Cost of fertilizer, polythene and rice straw)

Gross return = Yield × price

2.8 Statistical analysis

The statistical analysis of soil and plant data was done through the computer-based statistical program STAR (Statistical Tool for Agricultural Research), as outlined by Gomez and Gomez [9]. Significant effects of treatments were determined by analysis of variance (ANOVA), and treatment means were compared at the 5% level of significance by Duncan's Multiple Range Test (DMRT).

3. RESULTS

3.1 Effects on primary stem length

The primary stem length of bitter gourd increased significantly due to the single effect of mulch materials but was not significantly influenced by the single effect of K fertilizer and their interaction in both the years (2017-18 and 2018-19). Considering the single effect of mulch materials, the primary stem length ranged from 172.7 to 235.8 cm in 2017-18 and 197.2 to 268.1 cm in 2018-19, respectively. The highest primary stem length was always found in the polythene mulch treatment, which was significantly higher than the rice straw mulch treatment. Considering the single effect of K, 150% recommended K recorded the highest stem length of 211.0 and 221.4 cm in 2017-18 and 2018-19, respectively. The K-control treatment always had the lowest primary stem length. When the interaction effect was considered, polythene mulch × 150% recommended K fertilizer recorded significantly the highest primary stem length of 241.3 and 274.7 cm in two years, respectively (Table 1).

3.2 Effects on number of leaves per primary stem

Like the number of branches per plant, the number of leaves per primary stem of bitter gourd was significantly influenced by the single effect of mulching in both the years. The number of leaves

per primary stem ranged from 32.4 to 41.2 and 35.3 to 41.9 in 2017-18 and 2018-19, respectively. The highest number of leaves per primary stem was found in the polythene mulch treatment, which was significantly higher than the rice straw mulch and control treatments in both years. Rice straw mulch had statistically similar leaves per primary stem in the control treatment. K fertilizer had very little effect on increasing the number of leaves per primary stem. Although non significant, the highest leaf production was found at the 150% recommended K rate. The interaction effect of mulching × K fertilization was also not very impressive, as out of two years, only in thefirst yeara significant effect was found (Table 1).

3.3 Effects on number of branches per plant

There was a significant effect of mulch materials on the number of branches per plant of bitter gourd was found in both years but in case of K fertilizer a significant effect was found inonly first year.The number of branches per plant ranged from 5.9 to 10.3 in 2017-18 and 6.2 to 11.6 in 2018-19. In the first year, the highest number of branches per plant (10.3) was obtained from the polythene mulch treatment, which was significantly higher than the rice straw mulch (6.9) treatment. A similar trend was also found in the second-year trial. Generally, the rice straw mulch treatment had a positive effect on the number of branches per plant over the control treatment. The highest number of branches per plant recorded in the polythene mulch treatment clearly proved that polythene mulch made the soil comfortable for plant growth.Considering the single effect of K, the highest number of branches per plant was recorded in the 150% recommended K fertilizer dose, and the lowest was found in the K control treatmentin both years. In case of interaction effect, the highest number of branches per plant was recorded in polythene mulch × 150% recommended K fertilizer treatment in both the years (Table 2).

3.4 Effects on number of fruits per plant

The number of fruits per plant varied significantly due to the single effect of mulch materials, K fertilizer and their interactions in both the years (2017-18 and 2018-19). Considering the single effect of mulch, the highest number of fruits per plant of 18.0 and 15.0 was obtained from polythene mulchin first and second year, respectively which was significantly higher than the rice straw mulch treatment. The lowest number of fruits per plant of 7.0 and 8.0 was recorded in no mulch treatmentin first and second year, respectively.Considering the single effect of K fertilizer, the highest number of fruits per plant of 15.0 and 14.0 was obtained from 150% recommended K treatment in first and second year, respectively.In case of interaction effect, the highest number of fruits per plant of 23.0 and 19.0was recordedin polythene mulch × 150% recommended K fertilizer interaction in first and second year, respectively. The polythene mulch × 100% recommended K had the second rank on this parameter. Both the years and locations no mulch × no K fertilizer interaction had the lowest performance (Table 2).

No mulch× No K Rice straw mulch× 100% K Polythene mulch× 150% K

Fig. 1: Effect of mulching and K fertilization on number of fruits per plant at the time of first harvesting.

Table 1 Single and interaction effect of mulch materials and potassium fertilizer doses onprimary stem length and number of leaves per primary stem of bitter gourd at Barguna district of Bangladesh

Treatments	Primary stem length (cm)								Number of leaves per primary stem							
	2017-18				2018-19				2017-18				2018-19			
	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean
No mulch	167.0	163.3	187.7	172.7 C	193.0	199.3	199.3	197.2 B	30.0 Cb	31.3 Cb	36.0 Ba	32.4 B	34.0	34.0	38.0	35.3 B
Rice straw mulch	217.0	207.3	204.0	209.4 B	196.7	209.3	190.3	198.8 B	36.0 Ba	36.3 Ba	32.7 Ba	35.0 B	35.0	35.7	36.3	35.7 B
Polythene mulch	225.7	240.3	241.3	235.8 A	272.7	257.0	274.7	268.1 A	41.0 Aa	41.0 Aa	41.7 Aa	41.2 A	40.0	40.7	45.0	41.9 A
K mean	203.2	203.7	211.0		220.8	221.9	221.4		35.7	36.2	36.8		36.3 b	36.8 b	39.8 a	
Significance level	Mulch-***, K fertilizer-NS and interaction-NS				Mulch-***, K fertilizer-NS and interaction-NS				Mulch-***, K fertilizer-NS and interaction-NS				Mulch-***, K fertilizer-NS and interaction-*			
%CV	11.08				9.10				6.37				10.46			

Table 2 Single and interaction effect of mulch materials and potassium fertilizer doses onbranches per plant and number of fruits per plant of bitter gourd at Barguna district of Bangladesh

Treatments	Number of branches per plant								Number of fruits per plant							
	2017-18				2018-19				2017-18				2018-19			
	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean
No mulch	5.0	5.7	7.0	5.9 B	5.3	7.0	6.3	6.2 C	5.0Cb	7.0Ca	8.0Ca	7.0 C	7.0 Cb	8.0 Cb	10.0 Ca	8.0 C
Rice straw mulch	6.7	6.7	7.3	6.9 B	8.3	7.0	7.7	7.7 B	9.0Bb	13.0Ba	14.0Ba	12.0 B	9.0 Bc	11.0 Bb	13.0 Ba	11.0 B
Polythene mulch	9.0	9.3	12.7	10.3 A	11.3	11.0	12.3	11.6 A	12.0Ac	18.0Ab	23.0Aa	18.0 A	12.0Ac	14.0 Ab	19.0Aa	15.0 A
K mean	6.9 b	7.2 b	9.0 a		8.3	8.3	8.8		9.0 c	13.0 b	15.0 a		9.0 c	11.0 b	14.0 a	
Significance level	Mulch-***, K fertilizer-** and interaction-NS				Mulch-***, K fertilizer-NS and interaction-NS				Mulch-***, K fertilizer-NS and interaction-NS				Mulch-***, K fertilizer-* and interaction-NS			
%CV	14.32				10.73				8.87				10.63			

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT, NS= Not significant, CV= Co-efficient of variation, *= Significant at 5% level, **= Significant at 1% level, ***=Significant at 0.1% level

3.5 Effects on fruit yield

The fruit yield of bitter gourd increased significantly due to both the single and interaction effects of mulch materials and K fertilizer doses in both years. Across the years, the significantly highest fruit yield of 27.25 and 27.27 t $ha^{-1}$was found in polythene mulch treatment. The straw mulch treatment had better performance than the no mulch treatment. The lowest fruit yield of 11.56 and 9.16t $ha^{-1}$was always found with no mulch treatment in two years, respectively. Regarding the single effect of K, the significantly highest fruit yield of 22.22 and 20.51 t $ha^{-1}$was obtained from the 150% recommended K treatment in two years, respectively. Considering the interaction effect, the highest fruit yield of 32.67 and 34.88 t $ha^{-1}$was recorded in polythene mulch × 150% recommended K fertilizer interaction also in two years, respectively(Table 3). In terms of increasing fruit yield, polythene mulch and the 150% recommended K fertilizer interaction had outstanding performance. The highest increase in fruit yield over control of 250 and 364% was recorded in the polythene mulch × 150% recommended K fertilizer interaction in two years, respectively. Thus, the results indicated that polythene mulch along with the 150% recommended K fertilizer dose had the consistently best performance over the other treatment combinations.

Table 3 Single and interaction effect of mulch materials and potassium fertilizer doses on fruit yield of bitter gourd at Barguna district of Bangladesh

Treatments	Fruit yield (t ha^{-1})							
	2017-18				2018-19			
	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean
No mulch	9.34Cc	9.47Cb	15.88Ca	11.56C	7.52Cc	8.18Cb	11.78Ca	9.16C
Rice straw mulch	15.01Bc	15.14Bb	18.10Ba	16.08B	8.48Bc	14.15Bb	14.87Ba	12.50B
Polythene mulch	23.60Ac	25.48Ab	32.67Aa	27.25A	20.67Ac	26.27Ab	34.88Aa	27.27A
K mean	15.98c	16.70b	22.22a		12.22c	16.20b	20.51a	
Significance level	Mulch-***, K fertilizer-*** and interaction-***				Mulch-***, K fertilizer-*** and interaction-***			
%CV	10.47	10.52	%CV	10.47	10.52	%CV	10.47	10.52

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT, CV= Co-efficient of variation, ***=Significant at 0.1% level

3.5 Effects on leaf sodium (Na) content

The Na content in leaf varied significantly with the single effect of mulch and K fertilization in both the years.In the case of the interaction of mulch materials with K fertilizer significantly influenced the leaf Na content of bitter gourd only in second year. Over the years, the lowest leaf Na content of 1.91 and 1.63% was found in the polythene mulch treatment in two years, respectively which was significantly lower than the control and straw mulch treatments. In case of K fertilizer doses, the highest leaf Na content of 2.51 and 2.13% was found in the control (no K fertilizr) treatment in two years, respectively. The leaf Na content was decreased with the increase of K application rate. Considering the interaction effect, the highest leaf Na content of 2.77 and 2.49% was recorded in the control (no mulch × k control) treatment, and the lowest leaf Na content of 2.27 and 1.85% was recorded in the polythene mulch × 150% recommended K fertilizer interaction in two years, respectively (Table 4).

3.6 Effects on leaf potassium (K) content

The leaf K content was significantly varied due to thesingle effect of mulching and K fertilization and their interaction in both the years. The highest leaf K content of 2.27 and 2.08% was found in the polythene mulch treatment in two years, respectively. The K content in rice straw was higher than that of no mulch but significantly lower than that of polythene mulch. In thecase of K fertilizer doses, the lowest potassium content of 1.75 and 1.49% in two years, respectively. The potassium content gradually increased with the increase of K application rate. The highest leaf K content of 3.13 and 2.45% was recorded in the 150% recommended K dose in two years, respectively. In the case of the interaction effect, the highest leaf K content of 3.13 and 2.45%was recorded in the polythene mulch × 150% K fertilizer interaction, and the lowest leaf K content of 1.34 and 0.78% was recorded in the no mulch × no K fertilizer interaction in two years, respectively(Table 4).

3.7 Effects on leaf Na:K ratio

The sodium and potassium ratio is an important determinant of salt tolerance in crops. The sodium and potassium ratio is more detrimental than the sole Na content of the leaf. A higher Na:K ratio makes plants toxic and deficient in K [10].In the experiment, polythene mulch had the lowest Na:K ratio across the years (Fig. 2-3). Rice straw mulch had a Na:K ratio higher than polythene mulch but lower than the control treatment. No mulch treatment always had the highest Na:K ratio. Generally, the application of K reduces the Na:K ratio in the leaf. There was a reverse relationship between the Na:K ratio and added K. It means that the Na:K ratio gradually decreased with the increase of added K. Therefore, 150% recommended K had the lowest Na:K ratio, and K control treatment had the highest Na:K ratio (Fig. 2-3).

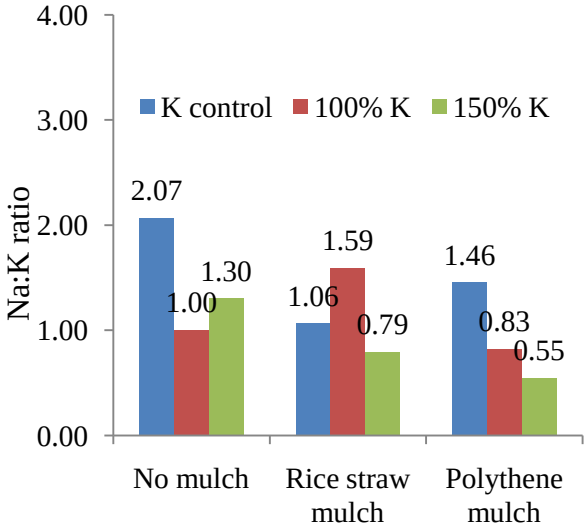

Fig. 2 Na:K ratio of bitter gourd leaf at Barguna district in the year 2017-18

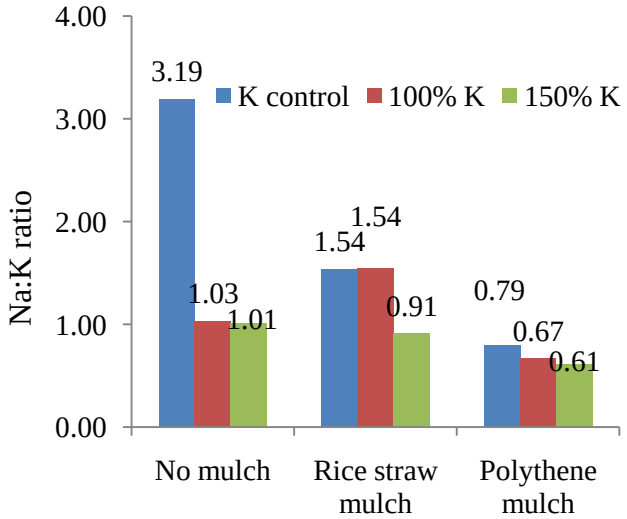

Fig. 3 Na:K ratio of bitter gourd leaf at Barguna district in the year 2018-19

3.8 Effects on soil electrical conductivity ($EC_{1:5}$)

The soil $EC_{1:5}$ varied significantly with different treatments over control in both the years. The highest soil $EC_{1:5}$ recorded from the control treatment which was significantly higher than the tested mulch materials. The lowest soil $EC_{1:5}$ of 2.23 and 1.91 dS/mwas consistently recorded in polythene mulch treatment in first and second years, respectively. The rice straw mulch reduced the soil $EC_{1:5}$ value by 62 and 52%, whereas the polythene treatment reduced it by 64 and 56% over the control treatment in two years, respectively. Regarding the K effect, the highest soil

$EC_{1:5}$ of 4.82 and 3.31dS/m was recorded in the control treatment, and the lowest soil $EC_{1:5}$ of 2.51 and 2.07 dS/mwas recorded in the 150% recommended K fertilizer in two years, respectively. The 150% recommended K fertilizer treatment reduced soil $EC_{1:5}$ value by 48 and 37% over the control treatment in two years, respectively. Considering the interaction effect, the lowest soil $EC_{1:5}$ recorded in polythene mulch × 150% recommended K fertilizer interaction in both the years (Table 5). The polythene much × 100% recommended K fertilizer interaction decreased soil $EC_{1:5}$ value by 81 and 70%, whereas the polythene much × 150% recommended K fertilizer interaction decreased by 82 and 81% over control treatment (no mulch and K control) in two years, respectively.

3.9 Effects on soil exchangeable sodium (Na) content

The exchangeable sodium (Na) content of the soil varied significantly with different treatments. Considering the single effect of mulch materials, the highest exchangeableNa content in soil (4.32 meq $100g^{-1}$ soil in first year and 5.27 meq $100g^{-1}$ soil in second year) was found in the in the control treatment, which was significantly higher than the polythene mulch treatment. The lowest exchangeableNa content in soil was recorded in the polythene mulch treatment. The rice straw mulch reduced soil exchangeableNa by 8 and 17%, whereas the polythene treatment reduced it by 23 and 24% over the control treatment in two years, respectively. The results further indicate that in the control treatment, exchangeableNa content is always higher, and in the polythene mulch condition, it was the lowest. Considering the single effect of K fertilizer, the lowest soil exchangeable Na content of 3.45 and 4.07 meq $100g^{-1}$ soil was recorded in the 150% recommended K dose in the years 2017-18 and 2018-19, respectively. In the control treatment, where no K was added, it consistently recorded the highest soil exchangeableNa content. The 100% recommended K fertilizer reduced soil exchangeableNa content by 16 and 10%, whereas 150% recommended K fertilizer reduced it by 22 and 19% over the control treatment in two years, respectively. The Na content gradually decreased with an increase in the rate of K application. The result indicated that the 150% recommended K fertilizer dose had the consistently best performance over the years. Considering the interaction effect, the result indicated that the lowest soil exchangeableNa content was recorded in polythene mulch × 150% recommended K fertilizer interaction in both the years. The polythene much × 100% recommended K fertilizer interaction reduced soil exchangeableNa by 42 and 78%, whereas the polythene much × 150% recommended K fertilizer interaction reduced Na by 75 and 81% over no mulch × no K (control) treatment in two years, respectively (Table 5).

Table 4 Single and interaction effect of mulch materials and potassium fertilizer doses onleaf Na and K content of bitter gourd at Barguna district of Bangladesh

Treatments	Leaf Na (%) content								Leaf K (%) content							
	2017-18				2018-19				2017-18				2018-19			
	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean
No mulch	2.77	2.34	2.03	2.38A	2.49Aa	1.61 Bb	1.58Bc	2.08A	1.34Bb	2.34Aa	1.56Cb	1.75B	0.78Bb	1.56Ba	1.56Ca	1.30 B
Rice straw mulch	2.49	2.13	1.86	2.06B	2.06Ba	2.07 Aa	2.12Aa	1.82B	2.34Aa	1.34Bb	2.34Ba	2.01AB	1.34Bb	1.34Bb	2.34Ba	1.68AB
Polythene mulch	2.27	1.76	1.71	1.91B	1.85Ca	1.56 Bb	1.49Bb	1.63C	1.56Bc	2.13Ab	3.13Aa	2.27A	2.34Ab	2.34Ab	2.45Aa	2.08 A
K mean	2.51 a	2.08 b	1.77 c		2.13a	1.75 b	1.66 b		1.75b	1.94ab	2.34a		1.49b	1.75a	1.82a	
Significance level	Mulch-***, K fertilizer-*** and interaction-NS				Mulch-***, K fertilizer-*** and interaction-***				Mulch-***, K fertilizer-*** and interaction-***				Mulch-***, K fertilizer-*** and interaction-***			
%CV	6.95				4.60				8.56				4.23			

Table 5 Single and interaction effect of mulch materials and potassium fertilizer doses on post-harvest soil $EC_{1:5}$and exchangeable Na content of bitter gourd at Bargunadistrict of Bangladesh

Treatments	$EC_{1:5}$ (dS/m)								Exchangeable Na (meq/100g soil)							
	2017-18				2018-19				2017-18				2018-19			
	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean	K control	100% K	150% K	Mulch mean
No mulch	7.24Aa	6.86Aa	4.82Ab	6.19A	5.82Aa	4.06Ab	3.22Ac	4.36A	6.49Aa	1.98Cc	4.49Ab	4.32A	9.16Aa	6.49Aa	6.49Aa	5.27A
Rice straw mulch	4.13Ba	1.70Bb	1.39Cb	2.37B	2.19Ba	2.17Ba	1.88Bb	2.08B	4.89Ba	5.50Aa	4.27Aa	3.99A	2.82Bb	6.11Aa	2.94Bb	4.36B
Polythene mulch	3.08Ba	1.37Cc	1.33Cb	2.23B	1.91Bb	1.72Cc	1.10Ba	1.91B	1.94Cb	3.77Ba	1.60Bb	3.33A	3.09Bb	1.99Bc	1.77Bb	3.99B
K mean	4.82a	3.31b	2.51c		3.31a	2.65b	2.07c		4.44a	3.75a	3.45a		5.02a	4.53ab	4.07b	
Significance level	Mulch-***, K fertilizer-*** and interaction-***				Mulch-***, K fertilizer-*** and interaction-***				Mulch-***, K fertilizer-** and interaction-***				Mulch-***, K fertilizer-NS and interaction-***			
%CV	3.94				3.84				7.07				4.53			

Similar small letters in a row or similar capital letters in a column are not significantly different at 5% level by DMRT, CV= Co-efficient of variation, **= Significant at 1% level, ***=Significant at 0.1% level, NS= Not significant.

3.10 Correlation matrix

The fruit yield of a crop is a complex character that results from the interactions of many characters. To examine the interrelationship of fruit yield with other plant and soil characteristics, a correlation matrix was done. The values of the correlation coefficient (r) with their level of significance are given in Table 6. It appears that fruit yield was positively and significantly correlated with primary stem length, the number of branches per plant, the number of leaves per primary stem, and the number of fruits per plant. Fruit yield was positively correlated with leaf potassium (K), but negatively and significantly correlated with leaf sodium (Na) content. The result of the correlation between yield and the nutrient contents of the leaf clearly revealed that the higher sodium concentration in the leaf reduced the fruit yield, whereas the potassium concentration increased fruit yield. Regarding soil properties, fruit yield was negatively correlated with soil EC and soil sodium (Na) contents.

Table 6 Correlation between fruit yield and different plant and soil parameters of bitter gourd

Variables	Fruit yield	
	2017-18	2018-19
Primary stem length	0.683***	0.811***
Number of leaves per primary stem	0.791***	0.776***
Number of branches per plant	0.727***	0.828***
Number of fruits per plant	0.787***	0.899***
Leaf sodium (Na)	-0.557**	-0.504**
Leaf potassium (K)	0.279^{NS}	0.241^{NS}
Soil EC	-0.333^{NS}	-0.465*
Soil sodium (Na)	-0.230^{NS}	-0.106^{NS}

*= Significant at 5% level, **=Significant at 1% level, ***=Significant at 0.1% level, NS= Not significant

3.11 Economic analysis

The economic analysis for the bitter gourd was done to find out the marginal benefit-cost ratio (MBCR) against different mulch and K fertilizer treatments. Over the years, polythene mulch, along with any rates of K (0, 100, and 15% recommended K), had consistently higher gross return and added benefit. Rice straw mulch had a lower return compared to the polythene mulch treatment. In the experiment, the highest added benefit was recorded in the polythene mulch × 150% recommended K combination (Table 7). The polythene mulch treatment had the highest MBCR except in a few cases. The K fertilizer did not much affect the MBCR value due to the use of a lower amount and a lower market price. In a few cases, no mulch treatment had the highest MBCR due to its very low added cost. But this treatment is not feasible for growing crops in the coastal saline region of Bangladesh because of soil salinity. Therefore, based on the MBCR value, polythene mulch along with the 150% recommended K could be advisable for progressive farmers. Straw mulch could also be recommended for farmers who want to invest a lower amount of money to get a satisfactory yield.

Table 7: Marginal benefit cost ratio (MBCR) of different mulchand potassium treatments of bitter gourd at Barguna district of Bangladesh

Treatments	2017-18				2018-19			
	Gross return (tk)	Added benefit (tk)	Added cost (tk)	MBCR (tk)	Gross return (tk)	Added benefit (tk)	Added cost (tk)	MBCR (tk)
M_1K_1	467083.3				375833.3			
M_2K_1	750416.7	283333.4	12500	22.7	743333.3	367500	12500	29.4
M_3K_1	1180000	712916.7	30000	23.8	1033333	657500	30000	21.9
M_1K_2	473500	6416.7	2500	2.6	409166.7	33333.37	2500	13.3
M_2K_2	507083.3	40000.03	15000	2.7	707500	331666.7	15000	22.1
M_3K_2	1633333	1166250	32500	35.9	1313333	937500	32500	28.8
M_1K_3	920000	452916.7	3750	120.8	588750	212916.7	3750	56.8
M_2K_3	794166.7	327083.4	16250	20.1	424166.7	48333.37	16250	3.0
M_3K_3	1274167	807083.4	33750	23.9	1744167	1368333	33750	40.5

M_1= no mulch, M_2= rice straw mulch, M_3= polythene mulch, K_1= no K fertilizer,K_2= 100% recommended K fertilizer and K_3= 150% recommended K fertilizer.

4. DISCUSSION

The yield and yield contributing characters (primary stem length, leaves per primary stem, branches per plant, and number of fruits per plant) of bitter gourd were higher in polythene mulch than other mulch treatments in both the years. It may be due to higher soil moisture within the root zone by restricting direct evaporation of soil water through the use of polythene mulch. Polythene mulching has consistently contributed to the retention of lower electrical conductivity (EC) and Na^+ concentrations with a higher concentration of K^+ in soil through conserving moisture. Thus, low concentrations of salt and high soil water under polythene mulch during the growing season were the main reasons for the higher yield and yield-contributing characteristics of bitter gourd. The results are also similar to the findings of different researchers [4]; [11]. Among all the K treatments, 150% recommended K had the highest results in yield and yield-contributing characteristics of bitter gourd in both the years. This is because 150% of recommended K fertilizer application increases more K^+ion concentration in the root zone than other tested treatments, which facilitates the balanced uptake of Na^+ and $K^+$by plants. Similar results were also found by different researchers [12]; [13]. In the case of interaction, the results indicated that polythene mulch along with the 150% recommended K fertilizer dose had the consistently best performance over the other tested treatment combinations in both the years. This is because polythene mulch maintains higher soil moisture within the root zone by restricting direct evaporation of soil water than without mulching, and the 150% recommended K application protects plants from salinity effects by facilitating a balanced uptake of Na^+ and K^+. The results are similar to the findings of Sanas *et al.* [14]. Over the years, the bitter gourd leaf contains the lowest amount of Na and the highest amount of K in the polythene mulch treatment compared to other treatments. The polythene mulch restricts the accumulation of Na in saline soils by conserving more soil moisture. Perhaps in no mulch condition, salts were accumulated in higher concentrations in the soil and concomitantly increased the uptake of Na. When Na uptake is higher, then K uptake is lower in plant tissue, and vice versa. For this reason, the lowest leaf Na

content and the highst leaf K content was found in polythene mulch treatment. These results were consistent with the earlier works [15]. Generally, 150% of the recommended K dose had the lowest Na and highest K content of leaf in both the years. Probably, higher rates of K compete well with Na for plant uptake. Similar results were found by some other researchers [16]. Considering the interaction effect, the lowest Na and highest K content of leaf were recorded in polythene mulch × 150% recommended K in both the years. This might be due to the lower Na uptake from the soil because higher doses of K inhibit the uptake of Na from the soil. On the other hand, the highest K content of leaf may be due to higher doses of the recommended K fertilizer. The soil $EC_{1:5}$ value and exchangeable Na concentration were highest in the control treatment and lowest in the polythene mulch treatment. The results clearly proved that polythene mulch is highly capable for reducing soil $EC_{1:5}$ value and Na concentration to a lower limit than other tested treatments by conserving the highest moisture level in the root zone. The results were consistent with the earlier works by Rahman *et al.*[17]. In the case of K fertilizer treatments, the highest and lowest soil $EC_{1:5}$ value and exchangeable Na concentration were recorded in the control treatment and the 150% recommended K fertilizer treatment, respectively. A similar result was found by Kaya *et al.*[18]. Considering interaction treatment, the lowest soil $EC_{1:5}$ value and exchangeable Na concentration were found in the control treatment and polythene mulch × 150% recommended K fertilizer interaction treatment, respectively. This is due to polythene mulch and the 150% recommended K fertilizer having the highest ability to reduce soil salinity ($EC_{1:5}$) and Na concentration compared to other treatments in the experiment. In the experiment, it was observed that when the polythene mulch was not used, the soil exchangeable Na was extremely high. At that condition, the application of the recommended 150% K fertilizer did not have any additional benefit, but it may restrict the uptake of soil sodium by balancing the Na^+:K^+ ratio in the soil. On the other hand, when the polythene mulch was used, the scenario was totally changed. The use of polythene drastically reduced soil sodium. Here, mulch materials reduce soil sodium by restricting evaporation losses and conserving more moisture in the soil. This may cause a reduction in soil Na value even with the combined application of mulch materials with K fertilizers. The results were consistent with the earlier works of Kaya *et al.*[18].In thecase of correlation study, a strong relationship was foundbetweenfruit yield and different soil and plant parameters. The strong relationship between fruit yield and all the soil and plant parametersrevealed that fruit yield was greatly influenced by those parameters. Similar findings were also observed in the earlier works [19]. Considering the gross return, polythene mulch always gave the highest value followed by rice straw mulch and control treatment in any amount of recommended K fertilizer in both the years. Gross return is directly related to the yield of the component crops and the prices that the producer receives for the produce [20]. Considering gross return over control, the polythene mulch was found to be an economically more profitable and viable treatment than the rice straw mulch treatment. The better economic performance of polythene mulch treatment was accomplished primarily due to higher fruit yield. Indeed, for achieving sustainable crop yield with reduced soil salinity, the polythene mulch approach deserves attention.

5. CONCLUSION

Several outputs, like increasing crop yield, reducing soil salinity, and introducing a new package for saline soil management, were brought out through the use of polythene mulch and potassium fertilizer in this study. So, polythene mulch and potassium fertilizer management approaches were found to be highly effective for reducing salinity and increasing crop production in coastal saline soils in Bangladesh. More specifically, the polythene mulch and 150% recommended K fertilizer

were the best among all the tested treatments. Therefore, polythene mulch and 150% recommended K fertilizer could be recommended as a new package for farmers' use in coastal saline soil management in Bangladesh to achieve a higher crop yield.

REFERENCES

1. Hasan MH, Rahman, MR, Haque A, Hossain T. Soil salinity hazard assessment in the Bangladesh coastal zone Proceedings of the International Conference on Disaster Risk Management, Dhaka, Bangladesh. 2019.
2. SRDI. Saline soils of Bangladesh, SFSDP program, soil resource development institute, Ministry of Agriculture, Government of the Peoples' Republic of Bangladesh. 2018.
3. MoA, FAO. Master Plan for Agricultural Development in the Southern Region of Bangladesh, Ministry of Agriculture, Government of the People's Republic of Bangladesh.2013.
4. Kumar T, Haque MA, Islam MS, Hoque MF, Jodder R. Effect of Polythene Mulch on Growth and Yield of Sunflower (*Helianthus annuus)* Archives of Crop Science. 2018;2(1):38-46.
5. Munir A, Shehzad MT, Qadir AA, Murtaza G, Khalid HI. Use of Potassium Fertilization to Ameliorate the Adverse Effects of Saline-Sodic Stress Condition (ECw: SARw Levels) in Rice (*Oryza Sativa* L.) Journal of Communications in Soil Science and Plant Analysis. 2019; 50(16):1975-1985.
6. Petersen L. Analytical Methods: Soil, Water, Plant Material and Fertilizer, Soil Resources Management, and Analytical Services Soil Resource Development Institute, Dhaka, 2002; 45-47.
7. Knudsen D, Petterson GA, Pratt PF. Lithium, sodium, and potassium In: Methods of Soil Analysis, Part 2, 2nd edition, Page A. L. Miller, R. H., and Keeney, D. R. American Society of Agronomy, Incorporated, Madison, Wisconsin, USA. 1982; pp. 643-693.
8. Kay RD. Farm Management: Planning, Control, and Implementation McGraw-Hill Book Company, New York, USA, 1981; p. 60.
9. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research: An International Rice Research Institute Book 2nd edition. A Wiley-Interscience Publication, John Wiley & Sons, New York. 1984.
10. Almeida DM, Oliveira MM, Saibo NJM. Regulation of Na^+ and K^+ homeostasis in plants: towards improved salt stress tolerance in crop plants. Genetics and Molecular Biology. 2017; 40(1): 326-345.
11. Helaly AA, Goda Y, Abd El-Rehim AS, Mohamed AA, El-Zeiny OAH. Effect of polyethylene mulching type on the growth, yield, and fruit quality of *Physalis pubescens*. 2017; 6(5):154-160. https://doi.org/10.15406/apar.2017.06.00229.
12. Sathappan CT, Sivanesh K, Dhanasekaran D. Studies on the influence of potassium on growth, yield, and quality of hill Banana var. Sirumalai. Plant Archives. 2019); 19(2):1603-1605.
13. Hartati S, Suryono, Purnomo D. Effectiveness and efficiency of potassium fertilizer application to increase the production and quality of rice in entisols Soil Science Department, Agriculture Faculty, Universitas Sebelas Maret, Surakarta, Indonesia IOP Conference Series: Earth and Environmental Science. 2016; p. 142.
14. Sanas K, Dilta BS, Singh S. Efficacy of mulch, N, and K applications on plant growth and yield characteristics in annual Chrysanthemum International Journal of Pure and Applied Bioscience. 2018; 6(6):1127-1138.

15. Bhardwaj, Raju L. Effect of mulching on crop production under rainfed conditions: a review Agricultural Reviews. 2012; 34 (3):188-197.

16. Kausar A, Ashraf MY, Gull M, Ghafoor R, Ilyas M, Zafar S, Niaz M, Akhtar N, Kanwal H, Iqbal, N, Aftab K. Alleviation of Salt Stress by K_2SO_4 in Two Wheat (*Triticum aestivum* L.) Cultivars. Applied Ecology and Environmental Research. 2016; 14(5):137-147.

17. Rahman MJ, Uddin MS, Bagum SA, Mondol AT, Zaman MM. Effect of mulches on the growth and yield of tomatoes in the coastal area of Bangladesh under rainfed conditions International Journal of Sustainable Crop Production. 2006; 1:6-10.

18. Kaya CAL, Tuna M, Ashraf, Altunlu H. Improved salt tolerance of melon (*Cucumis melo* L.) by the addition of proline and potassium nitrate. Environmental and Experimental Botany. 2007; 60(3):397-403.

19. Mollah MSH, Ali MA, Alam MR, Ahmed B, Hamidullah ATM. Productivity and profitability of crops in the Wheat-Mungbean-T. Aman rice pattern are influenced by different fertilizer packages and brown manuring. Bangladesh Journal of Agriculture and Environment. 2009; 5(2):69-78.

20. Singh RK, Bhora JS, Nath T, Singh Y, Singh K. Integrated assessment of diversification of the rice-wheat cropping system in the Indo-Gangetic Plain Archives of Agronomy and Soil Science. 2011; 57(5):489-506.

21. Butcher K, Wick AF, DeSutter T, Chatterjee A, Harmon J. Soil salinity: A threat to global food security. Agronomy Journal. 2016 Nov;108(6):2189-200.