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EFFECT OF DIFFERENT MULCHES AND PLANTING BEDS ON GROWTH AND YIELD OF BITTER GOURD IN COASTAL SALINE SOILS

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Abstract

A field experiment was carried out in coastal saline soils of Bangladesh in 2018, 2019 and 2020 to evaluate the effect of different kinds of mulches and planting beds to reduce salt accumulation in the soil and to increase the yield of bitter gourd. The experiment was laid out in a factional randomized complete block design having two kinds of mulches: *viz*. rice straw mulch and polythene mulch along with no mulch control and three kinds of planting beds: *viz*. convex bed, flat bed and concave bed. The polythene mulch treatment had highest fruit yield of 21.86, 27.20 and 20.49 t ha^{-1}, respectively followed by rice straw mulch and no mulch control treatment in 2018, 2019 and 2020, respectively. Polythene mulch reduced electrical conductivity of soil by 31% and soil sodium content by 42% compared to no mulch treatment. Polythene mulch also increased soil temperature and gravimetric soil moisture content which promoted plant growth. The convex bed method produced highest mean fruit yield of 18.37, 20.06 and 15.18 t ha^{-1} followed by the flat bed and concave bed method in the year 2018, 2019 and 2020, respectively. Combined use of polythene mulch and convex bed planting could provide greatest benefit to the farmers. The polythene mulch along with convex bed planting is therefore, recommended to get higher yield of bitter gourd and to reduce detrimental effect of salt on crop in coastal saline soils.

Keywords: Bitter gourd, convex bed; Na:K ratio; polythene mulch; saline soil.

Introduction

Salinity is a widespread environmental stress for crop plants in arid and coastal regions. Salinity in the soil and irrigation water restricts yield in about 20% of the global irrigated area which covers about 45 million ha (FAO, 2008). Increased salinity significantly reduced the growth and yield of crops including maize, mustard, sweet gourd, potato, chilli etc. (Haque *et al*., 2014; Ahmed *et al*., 2017; Haque *et al*., 2018). Huge effort has been made to develop saline soil management practices and different kinds of tillage systems so far developed. Among them raised bed planting with alternate furrow irrigation is gaining importance for row crops (Sayre, 2007; Devkota *et al*., 2013).

However, evaporation of water during the drying periods in raised bed alternate furrow irrigation system results in salt accumulation on the tops and side slopes of the raised beds (Richards, 1954). Such salt movement to the centre of the bed

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may damage young plants grown there (Brady and Well, 2013). The microsprinkler irrigation is another option which could be successfully used to cultivate plants for the reclamation of coastal saline land (Chu *et al*., 2015). However, furrow irrigation, flood irrigation or sprinkler irrigation requires huge amount of fresh water which is scarce in coastal saline areas; as such, water-saving irrigation regimes are needed (Sun *et al*., 2017). Growing high value vine crops in convex or concave pits and irrigate only in the foot of the crop may dilute the salt concentration in the root zone area which ultimately may contribute to higher crop yield.

Combining mulching and shape of the pit could be very effective because it changes the distribution of soil moisture and salinity in the vicinity of the crop root zone. Mulched drip irrigation has been shown to decrease soil evaporation considerably (Qi *et al*., 2018). Mulching technologies have also been shown to reduce total evapotranspiration, effectively promoted the growth of crops and increased the water use efficiency compared with the check (Li *et al*., 2018).

Mulching with crop residues in raised beds planting system has previously been shown to have great potential to reduce soil salinity in salt-affected areas (Devkota, 2011). However, crop residues are not always available in sufficient quantities for mulching due to their high demands as feed and fuel (Kienzler *et al*., 2012).

Polythene mulching along with convex or concave bed planting could be the powerful tool to manage saline soil. Because, polythene mulching significantly increased top layer soil temperature in early growth stage, reduced soil evaporation in the early stage and increase transpiration, accelerated plant growth and advanced maturity and help to reach higher yield and water use efficiency (Yang *et al*., 2018). Polythene mulching along with root zone irrigation can provide an alternative option to prevent the risk of soil salinization leading to land degradation, and enhance crop productivity in the arid regions (Tan *et al*., 2017).

The cucurbit vegetables are very much susceptible to salinity. Due to severe soil and water salinity the cucurbit vegetable production in the coastal areas are very small. Soil salinity also influenced some nutritional quality parameters including proline, sugar, sodium, potassium contents etc. The experiment is therefore undertaken to evaluate different kinds of mulch materials and different shapes of planting beds to increase bitter gourd yield in coastal seasonal fallow lands.

Materials and Methods

The experiment was conducted in the farmers fields during rabi seasons of 2018, 2019 and 2020, respectively at Kalapara upazila of Patuakhali district, and Taltali and Amtali upazila of Barguna district, Bangladesh. Experimental field was medium high land under the AEZ 13, Ganges Tidal Flood Plain Soil. Texturally the Kalapara upazila soil was loam having 11.6 % sand, 65.0 % silt and 23.4 % clay. The composite initial soil contained 5.66 pH, 0.09 % total nitrogen (N), 6.4 mg kg^{-1} available phosphorus (P) and 181.9 mg kg^{-1} available sulphur (S), and 37.84 meq $100g^{-1}$ soil exchangeable sodium (Na) and 0.35 meq $100g^{-1}$ soil exchangeable potassium (K), electrical conductivity determined in 1:5 soil water suspension was 0.67 dS m^{-1}. The Taltali upazila soil was silty clay loam having 32% clay, 65% silt and only 3% sand. The initial soil had 4.78 pH, 0.95 dSm^{-1} electrical conductivity ($EC_{1:5}$), 0.075% total N, 4.25 ppm available P, 141.4ppm available S contents. Regarding Amtali upazila texturally soil was again silty clay loam having 38% clay, 60% silt and only 2% sand. The initial soil had 4.54 pH, 0.71 dSm^{-1} $EC_{1:5}$, 0.050% total N, 2.83 ppm available P, 157.1ppm available S contents.

The experiment was laid out in a factional randomized complete block design with four replications. First factor for the experiment was the mulching methods having three levels comprising no mulch, rice straw mulch and polythene mulch; the second factor being three kinds (shapes) of seedling transplanting beds like convex bed, flat bed and concave bed. The raised bed and flat bed planting are widely used for crop cultivation in Bangladesh; few coastal farmers also practiced concave bed planting as they believe that in the concave bed the salt accumulation is lower and keep higher soil moisture content. Therefore, the said three kinds of planting beds were taken as treatment in the experimental. The nine treatment combinations were randomly distributed to the plots in each block. The test crop was bitter gourd and the crop variety was Lalteer hybrid Korola-Tia.

The whole land was prepared by ploughing followed by laddering three times. For planting of seedlings one meter diameter circular area was further prepared by a spade to make soil fine. In the experiment three kinds of seedling planting beds were prepared. In the flat bed type there was no change in soil surface and it was parallel to the field soil. The convex bed type was prepared by making the bed at least 5 cm high than the field soil level. The center of concave bed was at least 5 cm lower than the field level. The shape of different kinds of seedling planting beds is shown in Fig. 1. In polythene mulch system the seedling transplanting bed (pit) soil was covered with a one square meter size blue colour polythene sheet. In rice straw mulch system the seedling planting beds were covered with rice straw @ 5 t ha^{-1}.

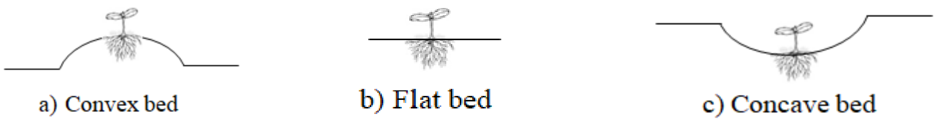

Fig. 1 Structure of different kinds of seedling planting beds.

Seedlings were raised in 10cm polybags. Fully decomposed cowdung was mixed with the soil and the polybag were filled with soil-cowdung mixture. One sprouted seed was sown in each polybag. The seedlings in the polybags were watered whenever necessary. Twenty day old healthy seedlings were used for transplanting. In polythene mulch system the seedlings were transplanted in soil within the 5 cm diameter round-cut portion in the center of the polythene sheet on 08 January 2018, 05 January 2019 and 01 January 2020, respectively. Plant spacing for all the treatments was 2m × 2m.

The land was fertilized with N, P and K @ 75, 30 and 50 kg ha^{-1}, respectively. The source of N, P and K were urea, triple super phosphate (TSP) and muriate of potash (MoP), respectively. In all the experimental plots TSP and MoP were applied during final land preparation. Urea was applied in three equal splits at 10, 25 and 45 days after transplanting. An amount of 1000 ml irrigation water twice in a week was given in the foot of each plant.

Data on soil temperature were recorded on 06th March 2018 at 1.00 pm. Soil samples were collected in the same date from the foot of each plant and analyzed for determination of pH in 1:2.5 soil water suspension, electrical conductivity in 1:5 soil water suspension, and chloride and bicarbonate ion contents by volumetric analysis method following standard procedures. The mature fruits were harvested four times with one week interval. The yield data were expressed as fresh weight basis. The mature fruits were chemically analysed for proline (Bates *et al*. 1973), total sugar (Dubois *et al.,* 1956), and sodium and potassium contents (Yoshida *et al*., 1976). The fruit chemical analysis data were presented as fresh weight basis. The chemical analysis of plant and soil samples was done in the laboratory of the Department of Soil Science, Patuakhali Science and Technology University, Bangladesh. Data recorded on soil and crop characters were subjected to statistical analysis through computer based statistical program STAR (Statistical Tool for Agricultural Research).

Results and Discussion

Fruit yield of bitter gourd

Fruit yield of bitter gourd was significantly and consistently influenced by mulching and planting bed types in 2018, 2019 and 2020 (Table 1); the interaction effect was significant only in 2019 and 2020 (Table 2). Based on the three years results mulch treatments had significantly higher fruit yield over no mulch control treatment. Among the mulches polythene mulch showed significantly higher performance than rice straw mulch treatment. The polythene mulch treatment had highest fruit yield of 21.86, 27.20 and 20.49 t ha^{-1}, which was 13.16, 17.51 and 11.71 t ha^{-1} in rice straw mulch treatment, and that of 6.71, 12.04 and 8.99 t ha^{-1} in no mulch control treatment in the year 2018, 2019 and

2020, respectively (Table 1). The polythene mulch treatment had fruit yield 225, 126 and 128 % higher than no mulch treatment, and 66, 55 and 75 % higher than rice straw mulch treatment in 2018, 2019 and 2020, respectively (data not shown in table). Considering single effect of planting beds the convex bed planting had significantly higher fruit yield than concave bed planting. The flat bed planting had intermediate fruit yield of convex bed and concave bed. In value the convex bed produced mean fruit yield of 18.37, 20.06 and 15.18 t ha^{-1}; the flat bed produced 12.99, 19.40 and 13.54 t ha^{-1}, and concave bed produced 10.36, 17.29 and 12.47 t ha^{-1} in the year 2018, 2019 and 2020, respectively. If we consider the interaction effect it was found that across the planting bed system polythene mulch had the highest performance. In the experiment polythene mulch along with convex bed planting consistently had the highest fruit yield (Table 2).

The increased yield in polythene mulch treatment was the outcome of increased vegetative and reproductive growth in this treatment (Table 1). Li *et al*. (2018) also found highest yield and water use efficiency in polythene mulch treatment compared to other tested seven mulch materials. Comparatively lower yield in no mulch and straw mulch treatment was due to development of salinity in the soil. The flat bed and concave bed could not give favorable soil environment for optimum plant growth. In supporting the findings Li *et al.* (2017) described that ridge planting will be more sustainable and effective than flat planting for reclamation of saline soils in coastal regions.

Table 1. Single effect of mulching and planting bed on fruit yield of bitter gourd in 2018-20

Treatments	Fruit yield in 2018 (t ha^{-1})	Fruit yield in 2019 (t ha^{-1})	Fruit yield in 2020 (t ha^{-1})
Mulching			
No mulch	6.71 c	12.04 c	8.99 c
Straw mulch	13.16 b	17.51 b	11.71 b
Polythene mulch	21.86 a	27.20 a	20.49 a
Significance level	***	***	***
Planting bed			
Convex bed	18.37 a	20.06 a	15.18 a
Flat bed	12.99 b	19.40 b	13.54 ab
Concave bed	10.36 c	17.29 c	12.47 b
Significance level	***	*	**
%CV	10.23	11.43	11.80

Means within each column showing similar letter are not significantly different.

Table 2. Interaction effect of mulching and planting bed on fruit yield of bitter gourd in 2018-2020

Treatments	Convex bed	Flat bed	Concave bed
	Fruit yield in 2018 (t ha^{-1})		
No mulch	11.80	5.11	3.21
Straw mulch	16.89	12.50	10.09
Polythene mulch	26.42	21.38	17.78
Significance level	Not significant		
	Fruit yield in 2019 (t ha^{-1})		
No mulch	14.63 bA	13.55 cA	7.94 cB
Straw mulch	17.70 bA	17.40 bA	17.43 bA
Polythene mulch	27.84 aA	27.25 aA	26.50 aA
Significance level	Significant at 5% level		
	Fruit yield in 2020 (t ha^{-1})		
No mulch	9.29 bA	9.32 cA	8.37 cA
Straw mulch	11.52 bA	12.41 aA	11.21 bA
Polythene mulch	24.71 aA	18.91 bB	17.84 aB
Significance level	Significant at 5% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Growth and yield contributing characters

Significantly highest stem length of 1.64m, number of branches per plant of 13.5, number of leaves per plant of 31.8, number of fruits per plant of 11.5, and fruit length of 23.7 cm were found in polythene mulch treatment (Table 3). Most of the cases rice straw mulch treatment had statistically similar but little bit higher results of no mulch treatment. Over the growth and yield parameters convex bed planting had significantly higher performance than concave and flat bed planting. When we consider the combined effect it was found that with one exception (in number of leaves per plant) every case the polythene mulch plus convex bed planting had the outstanding performance (Table 4). Equivalent results were also reported by Haque *et al*. (2018).

Table 3. Single effect of mulching and planting bed on growth and yield contributing characters of bitter gourd in 2018

Treatments	Primary stem length (m)	Branches per plant (no.)	Leaves per primary stem (no.)	Fruits per plant (no.)	Fruit length (cm)
Mulching					
No mulch	1.52 ab	10.5 b	27.7 b	6.2 b	20.7 b
Straw mulch	1.38 b	8.4 c	25.3 b	5.6 b	20.8 b
Polythene mulch	1.64 a	13.5 a	31.8 a	11.5 a	23.7 a
Significance level	***	***	***	***	***
Planting bed					
Convex bed	1.85 a	14.1 a	31.5 a	10.6 a	23.1 a
Flat bed	1.42 b	11.4 b	28.3 a	6.4 b	21.1 b
Concave bed	1.28 b	6.9 c	24.9 b	6.3 b	20.9 b
Significance level	***	***	***	***	***
%CV	6.62	10.81	7.85	11.41	4.43

Table 4. Interaction effect of mulching and planting bed on growth and yield contributing characters of bitter gourd in 2018

Treatments	Convex bed	Flat bed	Concave bed
	Primary stem length (m)		
No mulch	1.81 a A	1.51 a B	1.25 b C
Straw mulch	1.83 a A	1.17 bB	1.13 bB
Polythene mulch	1.90 aA	1.58 aB	1.45 aB
Significance level	Significant at 5% level		
	Branches per plant (no.)		
No mulch	13.3 b A	11.8 bA	6.5 bB
Straw mulch	13.8 abA	7.8 cB	3.8 cC
Polythene mulch	15.3 a A	14.8 aA	10.5 aB
Significance level	Significant at 0.1% level		
	Leaves per primary stem (no.)		
No mulch	31.0 aA	29.3 bA	22.8 bB
Straw mulch	30.8 aA	22.0 cB	23.0 bB
Polythene mulch	32.8 aA	33.5 aA	29.0 aB
Significance level	Significant at 1% level		
	Fruits per plant (no.)		
No mulch	9.5 bA	4.8 bB	4.3 bB
Straw mulch	9.3 bA	3.3 bB	4.3 bB
Polythene mulch	13.0 aA	11.3 aB	10.3 aB
Significance level	Significant at 5% level		
	Fruit length (cm)		
No mulch	21.4 bA	20.3 bA	20.4bA
Straw mulch	21.5 bA	20.4 bA	20.5 abA
Polythene mulch	26.4 aA	22.8 aB	21.9 aB
Significance level	Significant at 1% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Fruit quality parameters

The fruit proline, total sugar, sodium and potassium content, and the ratio of Na:K content were significantly influenced by single effect of mulch and bed systems, and their interactions. The mean proline content in control treatment was as 43.55 mg 100^{-1}g fruit which was significantly higher than rice straw mulch and polythene mulch treatment. The lowest proline content (22.57 mg $100g^{-1}$ fruit) was found in polythene mulch treatment which was statistically at par with rice straw mulch treatment (Table 5). Among the planting beds the lowest proline content (27.16 mg $100g^{-1}$ fruit) was recorded at convex bed planting system. If we consider the interaction effect it was found that at all the bed systems no mulch treatment had the highest poline content (Table 6). Similarly lowest proline content was consistently found in polythene mulch treatment. Proline is an important amino acid used to osmotic adjustment making plants stress tolerant especially in saline condition (Dar *et al*., 2016). During salt stress plants accumulate large amount of proline in cell sap. Thus higher accumulation of proline is the indicative of growing plants in excessive saline conditions. In the experiment lowest proline content in polythene mulch treatment indicates that these plants were not affected or less affected by salinity. Similarly lowest proline content in convex bed planting indicates its comfortable soil environment.

Total sugar content was found increased due to use of polythene mulch (2.44 g $100g^{-1}$ fruit) compare to no much treatment (1.41 g $100g^{-1}$ fruit). Bed system also had a positive effect having highest total sugar content in convex bed planting (2.14). Among the treatment combinations the polythene mulching along with convex bed planting had highest fruit sugar content of 3.09 g $100g^{-1}$ fruit (Table 6).

The fruit Na content in no mulch, rice straw mulch and polythene mulch treatment was 1.56, 1.19 and 0.64 %, respectively (Table 5). Therefore, rice straw much and polythene mulch reduced Na content by 24 and 59 %, respectively compared to no mulch treatment. Among the planting beds convex bed had lowest fruit Na content of 0.84%. The flat bed and concave bed had statistically similar fruit Na content. Considering interaction effect across the planting bed systems polythene much had the lowest Na content. Furthermore, polythene mulch with convex bed planting had lowest fruit Na content of 0.441%. The lower Na content was one of the major reasons of higher yield in convex bed planting system.

Unlike Na, K content of fruit was increased due to use of mulch materials. The K content significantly higher in straw mulch (0.371%) compare to control (0.328%), and significantly higher in polythene much compared to straw mulch treatment (0.431%) (Table 5). Among the planting beds, convex bed had highest fruit K content (0.393%). The flat bed and concave bed had statistically similar K content. The single effect of mulching and planting beds had a positive effect on interaction effect; highest K content (0.488%) is therefore found in polythene mulch and convex bed planting combination (Table 6).

The fruit Na:K ratio is an important indication which determining the level of Na toxicity in plants, higher the value indicates higher toxicity in plants. In the experiment the control, straw mulch and polythene mulch treatment had Na:K ratio of 4.768, 3.249 and 1.528 which clearly indicates that under polythene mulch treatment plants faces very minimum level of Na toxicity. Among the planting beds convex bed planting had lowest Na:K ratio of 2.411 (Table 5). When combined effect was considered it was found that polythene mulching along with convex bed planting had the lowest fruit Na:K ratio of 0.906, which means that in this treatment combination K ion successfully dominated over Na ion in the salt affected soils (Table 6).

It has been reported previously that higher Na:K ratio makes plant Na toxic and deficient in K (Almeida *et al.* 2017). In the present experiment polythene mulch had Na:K ratio several fold lower than both straw mulch and no mulch treatment. Similarly convex bed treatment had significantly lower Na:K ratio than flat bed and concave bed treatment. Thus under the polythene mulch and convex bed planting treatment combination plants enjoy least saline environment which might have been safer for growing bitter gourd.

Table 5. Single effect of mulching and planting bed on fruit nutritional quality characters of bitter gourd in 2018

Treatments	Fruit proline content (mg $100g^{-1}$ fruit)	Fruit total sugar content (g $100g^{-1}$ fruit)	Fruit Na content (%)	Fruit K content (%)	Fruit Na:K ratio
Mulching					
No mulch	43.55 a	1.41 c	1.56 a	0.328 c	4.768 a
Straw mulch	23.61 b	1.58 b	1.19 b	0.371 b	3.249 b
Polythene mulch	22.57 b	2.44 a	0.64 c	0.431 a	1.528 c
Significance level	***	***	***	***	***
Planting bed					
Convex bed	27.16 b	2.14 a	0.84 b	0.393 a	2.411 c
Flat bed	31.97 a	1.63 b	1.26 a	0.370 b	3.550 b
Concave bed	30.60 a	1.67 b	1.29 a	0.367 b	3.584 a
Significance level	***	***	***	***	***
%CV	5.65	4.79	4.20	3.45	5.75

Means within each column on showing similar letter are not significantly different

Table 6. Interaction effect of mulching and planting bed on fruit nutritional quality characters of bitter gourd in 2018

Treatments	Convex bed	Flat bed	Concave bed
Fruit proline content (mg $100g^{-1}$ fruit)			
No mulch	39.57 aB	48.94 aA	42.13 aB
Straw mulch	21.28 bB	24.57 bA	24.98 bA
Polythene mulch	20.62 bB	22.40 bAB	24.68 bA
Significance level	Significant at 1% level		
Fruit total sugar content (g $100g^{-1}$ fruit)			
No mulch	1.48 cB	1.64 bA	1.11 cC
Straw mulch	1.85 bA	1.36 cC	1.54 bB
Polythene mulch	3.09 aA	1.88 aC	2.35 aB
Significance level	Significant at 0.1% level		
Fruit Na content (%)			
No mulch	1.382 aC	1.838 aA	1.471 aB
Straw mulch	0.688 bC	1.491 bA	1.397 aB
Polythene mulch	0.441 cB	0.461 cB	1.014 bA
Significance level	Significant at 0.1% level		
Fruit K content (%)			
No mulch	0.304 cB	0.341 bA	0.338 cA
Straw mulch	0.388 bA	0.363 bB	0.363 bB
Polythene mulch	0.488 aA	0.405 aB	0.400 aB
Significance level	Significant at 0.1% level		
Fruit Na:K ratio			
No mulch	4.550 aB	5.395 aA	4.358 aB
Straw mulch	1.776 bB	4.116 bA	3.855 bA
Polythene mulch	0.906 cB	1.141 cB	2.538 cA
Significance level	Significant at 0.1% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Soil physical and chemical properties

The mulch treatments significantly influenced the temperature of soil having mean 39.4ºC in polythene mulch, 32.1ºC in straw mulch and 33.3ºC in control (no mulch) treatment (Table 7).Therefore, the results clearly indicated that polythene much helps to keep soil warm and rice straw mulch keeps soil cool compare to unmulched conditions. The planting beds had no significant effect on soil temperature, although convex bed planting had to some extent increased soil temperature. Considering the combined effect it was found that the polythene mulch along with convex bed planting had highest soil temperature of 42.3ºC (Table 8). Due to high soil temperature the soil nutritional and biological property is improved which ultimately increased the yield of crop. Soil temperature is an important factor for growing crops especially in winter season. Dong *et al.* (2018) reported that polythene mulch is an effective strategy for promoting crop emergence and rapid growth of crops because it can modify the soil microclimate by increasing the soil temperature.

A highly significant effect of using mulch on gravimetric soil moisture content having 6.2, 12.1 and 18.5 % in no mulch, straw mulch and polythene mulch treatment, respectively was found (Table 7). Rice straw mulch and polythene mulch increased moisture content by 95 and 198 % over control (no mulch) treatment. Looking interaction effect it was found that convex bed planting had comparatively lower moisture content in no mulch and straw mulch treatment. However, convex bed planting with polythene mulch combination conserve a highest (20.5%) soil moisture content (Table 8). Li *et al*. (2018) tested 7 mulching materials to grow maize crop and stated that all the mulches saved water and accelerated maize growth in the middle and later stages; highest performance being in polythene mulches. Polythene mulch increased the amount of soil-available water by restricting evaporation and elevating deepwater by capillarity and vapor transfer to the layer usable for roots under arid and semi-arid conditions (Qin *et al*., 2014).

Table 7. Single effect of mulching and planting bed on soil physical and chemical parameters in 2018

Treatments	Soil temperature (ºC)	Soil moisture content (%)	Soil $EC_{1:5}$ (dS/m)	Na content of soil (meq/100g soil)	Bicarbonate ion content (%)	Chloride ion content (%)
Mulching						
No mulch	33.3 b	6.2 c	3.67 a	7.63 a	0.550 a	0.183 a
Straw mulch	32.1 b	12.1 b	3.13 b	6.46 b	0.442 a	0.121 b
Polythene mulch	39.4 a	18.5 a	2.55 c	4.44 c	0.244 b	0.041 c
Significance level	***	***	***	***	**	***
Planting bed						
Convex bed	36.1	11.3	2.23 C	6.12	0.376	0.121
Flat bed	34.5	13.2	3.15 B	6.35	0.450	0.108
Concave bed	34.3	12.3	3.97 A	6.05	0.410	0.115
Significance level	NS	NS	***	NS	NS	NS
%CV	4.59	10.64	7.85	8.78	36.61	18.35

Means within each column are not significantly different

Table 8. Interaction effect of mulching and planting bed on soil physical and chemical parameters in 2018

Treatments	Convex bed	Flat bed	Concave bed
	Soil temperature (ºC)		
No mulch	33.5 bA	33.8 bA	32.8 bA
Straw mulch	32.5 bA	31.5 bA	32.3 bA
Polythene mulch	42.3 aA	38.3 aB	37.8 aB
Significance level	Significant at 5% level		
	Soil moisture content (%)		
No mulch	4.2 cB	5.7 cB	8.7 cA
Straw mulch	9.1 bB	14.3 bA	12.9 bA
Polythene mulch	20.5 aA	19.7 aA	15.2 aB
Significance level	Significant at 0.1% level		
	Soil $EC_{1:5}$ (dS/m)		
No mulch	2.67 aC	3.47 aB	4.88 aA
Straw mulch	2.11 bC	3.15 abB	4.12 bA
Polythene mulch	1.91 bB	2.84 bA	2.90 cA
Significance level	Significant at 1% level		
	Na content of soil (meq/100g soil)		
No mulch	7.88 aA	7.65 aA	7.35 aA
Straw mulch	6.57 bA	5.98 bA	6.82 aA
Polythene mulch	3.90 cB	5.43 bA	3.98 bB
Significance level	Significant at 5% level		
	Bicarbonate ion content (%)		
No mulch	0.551	0.575	0.525
Straw mulch	0.352	0.525	0.450
Polythene mulch	0.225	0.250	0.256
Significance level	Not significant		
	Chloride ion content (%)		
No mulch	0.183	0.174	0.192
Straw mulch	0.131	0.120	0.112
Polythene mulch	0.050	0.031	0.042
Significance level	Not significant		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Electrical conductivity of soil is an important parameter that determines the level of salinity in soil which was extremely influenced by mulching and planting beds. It was observed that under the no mulch, straw mulch and polythene mulch methods $EC_{1:5}$ of 3.67, 3.13 and 2.55 dS m^{-1}, respectively was recorded (Table 7). The straw much and polythene mulch reduced $EC_{1:5}$ by 15 and 31 %, respectively over control. Similarly, from convex bed, flat bed and concave bed methods mean $EC_{1:5}$ of 2.23, 3.15 and 3.97 dS m^{-1}, respectively were recorded. Looking the interaction effects (Table 8), it was found that across the planting beds polythene much had always the lower EC, the least value (1.91 dS m^{-1}) being in the polythene mulch with convex bed planting system. Zheng *et al*., (2009) found a negative relation of EC with yield and identified as the key limiting factor for cotton growth under the drip irrigation system. Previously Haque *et al*. (2018) reported that use of polythene mulch significantly reduces electrical conductivity of soil which is in agreement with the present study.

Sodium content is another important parameter which determines the level of salt toxicity. When mulches were used the EC value was 7.63 meq $100g^{-1}$ soil, in rice straw mulch it was 6.46 meq $100g^{-1}$ soil and in polythene much treatment it was 4.44 meq $100g^{-1}$ soil, which indicates that polythene mulch was able to reduce Na content of soil by 42 % over no mulch (control) treatment. However, planting beds had no positive effect on Na content of soil. Similar to Na ion concentrations, the bicarbonate and chloride ion content was also significantly influenced by mulch treatments (Table 7). In both of the cases polythene much had several times lower amount compared to the control treatment. The straw mulch treatment also had lower bicarbonate and chloride ion content compared to the no mulch treatment.

Economic profitability analysis

The economic viability of using different mulch materials under different planting bed systems was determined through calculation of marginal benefit-cost ratio (MBCR) of the mulch treatments. The economic analysis was done using three year mean fruit yield data. The summary result is shown in Table 9. Marginal benefit-cost ratio (MBCR) is the ratio of marginal or added benefits and added costs. To compare different mulch treatments with no mulch control treatment under different planting bed system the following formula was used.

$$\text{MBCR(over no mulch control)} = \frac{\text{Gross return in mulch treatment-Gross return in no mulch treatment}}{\text{Variable cost in mulch treatment-Variable cost in no mulch treatment}}$$

$$\text{MBCR (over no mulch control)} = \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}}$$

$$\text{Gross return} = \text{Yield} \times \text{price}$$

Under convex bed planting system the straw mulch and polythene mulch had MBCR of 8.7 and 12.0, but in flat bed system these two mulch materials gave MBCR of 11.9 and 11.0, respectively (Table 9). If we consider the concave bed planting system the rice straw mulch and polythene mulch gave MBCR of 16.0 and 11.8, respectively. Under convex bed planting system polythene mulch treatment had 38% higher MBCR compared to rice straw mulch treatment. Therefore, based on the higher yield and economic profitability the polythene mulch and convex bed planting combination could be recommended for growing vine crops in the coastal saline soils of Bangladesh. Based on the present experiment flat bed and concave bed system is not recommended due to significantly lower yield, rather convex bed was recommended due to higher yield and the ability to reduce salinity.

Table 9. Economic profitability of using different mulch materials under different bed systems for growing bitter gourd in coastal saline soils

Treatments	Gross return (Tk)	Added benefit (Tk)	Added cost (Tk)	MBCR
Convex bed planting system				
No mulch	595354	-	-	-
Straw mulch	768646	173292	20000	8.7
Polythene mulch	1316063	720709	60000	12.0
Flat bed planting system				
No mulch	466260	-	-	-
Straw mulch	705146	238886	20000	11.9
Polythene mulch	1125594	659334	60000	11.0
Concave bed planting system				
No mulch	325271	-	-	-
Straw mulch	645479	320208	20000	16.0
Polythene mulch	1035406	710135	60000	11.8

Values generated through calculation therefore, statistical analysis was not performed

Price: Bitter gourd- Tk 50000 t^{-1}, Rice straw- Tk 20000 ha^{-1}, Polythene mulch- Tk 60000 ha^{-1}

Conclusion

A suitable and profitable technology is far behind to manage saline soil as well as to improve crop production, as soil salinity seriously hampers the crop production in the coastal regions. Polythene mulch was found very much promising to manage saline soil because it improves crop yield through reducing soil salinity, and increasing soil temperature and moisture content. The convex bed planting could also be a potential tool to increase bitter gourd yield in the saline soils. The combination of the two techniques- polythene mulch and convex bed planting could produce the greatest benefit in bitter gourd cultivation under saline conditions with coastal areas.

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