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Enhancing yield potential and nutrient acquisition of cotton as influenced by super absorbent polymer (Pusa hydrogel) with stress management practices under rainfed vertisol

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ABSTRACT : A field experiments were conducted at Tamil Nadu Agricultural University, Regional Research Station, Aruppukottai during *rabi* season of 2016 and 2017 to study the impact of *insitu* moisture conservation and stress management practices on nutrient uptake and productivity of cotton under rainfed vertisol with the test variety SVPR 2. The experiments were laid out in split plot design replicated thrice. The main plot treatments consisted of different *insitu* moisture conservation measures *viz.,* broad bed and furrows (I_1), Ridges and furrows (I_2) and Compartmental bunding (I_3). The sub plot comprises with stress management practices *viz.,* Soil application of pusa hydrogel @ 5 kg/ha ($S\text{-}_1$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) ($S\text{-}_2$) , Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of (5%) Kaolin ($S\text{-}_3$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha ($S\text{-}_4$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of salicylic acid 100 ppm ($S\text{-}_5$) and control ($S\text{-}_6$). The results of this study showed that treatment combination of broad bed and furrow and soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha recorded efficient N, P and K uptake by the plants and higher seed cotton yield 1,580 kg/ha (2016) and 1,943 kg/ha (2017).

Key words : Broad bed and furrows, pusa hydrogel, rainfed cotton

Cotton, popularly known as **"White Gold"** is cultivated mainly for fibre. In addition to this, cotton seed is the second most important source of edible oil. India has been the traditional home of cotton and their textiles. India has progressed substantially in improving both production and productivity of cotton over the last five years, transforming from a net importer of cotton, to becoming one of the largest exporters, shipping 6.9 million bales followed by USA (Kannan *et al.*, 2017).

Cotton cultivation is very important part in the Indian agrarian landscape and provides sustainable livelihood to a sizeable population in India. India devotes more area to cotton than any other country in the world. At present, India ranks first in area with 11.88 M/ha, accounting 30 per cent of world coverage and 22 per cent (351 lakh bales of lint) of the world cotton production with a productivity of 568 kg/ha. It is estimated that more than 5.8 million farmers cultivate cotton in India. About 40-50 million people are employed directly or indirectly by the cotton industry. Nearly 65 per cent of the cotton crop is cultivated under rainfed condition in the country. In Tamil Nadu, 1.33 lakh ha is under cotton cultivation with production of 6.5 lakh bales with productivity of 620 kg/ha (Anonymous, 2014).

The crop prefers medium to deep black clayey soil, but is can also be grown in sandy and sandy loam soil with supplemental irrigation. Cotton is best grown in soils with an excellent water holding capacity. Aeration and proper drainage are equally important as the crop cannot withstand excessive moisture and water logging condition. The moisture stress is the primary cause for yield reduction in cotton. Like most of the major agricultural crops, cotton production and productivity is negatively influenced by moisture stress. Nearly, 60 per cent cotton growing area falls under rainfed conditions and characterized by scarcity of soil moisture. Depending upon the extent of residual soil profile moisture and scarce winter rains, cotton suffers to varying degree due to mounting moisture stress and consequently the productivity declines. To combat such adverse soil moisture scarcity conditions, matching integrated drought management practices need to evolved.

Rainfed areas can be made productive and profitable by adopting improved technologies for rainwater conservation and harvesting and commensurate agricultural production technologies. Soil management practices are tailored to store and conserve as much rainfall as possible by reducing runoff and increasing storage capacity of soil profile. The most efficient and cheapest way of conserving rainfall is to hold it *insitu.* In dry land soils *insitu* moisture conservation ensured higher moisture status in the profile, which provides a favourable environment for plant growth and response to applied nutrients.

The moisture stress during crop growth period is the primary cause for the yield reduction in cotton. To improve the soil moisture availability, by reducing the evaporation losses and retaining the moisture in effective rooting zone. The soil application of superabsorbent polymers (SAPs) is found to be the promising methodology in rainfed areas. However, very limited research work has experimented on this. One of such developed product is 'Pusa hydrogel' which is first successful an indigenous semi-synthetic superabsorbent technology for conserving water and enhancing crop productivity and thereby increases the water use efficiency (IARI, 2015). It performs its wetting or drying cycles over a longer period of time, maintaining its very high water swelling and releasing capacity against soil pressure. Consequently evaporation, deep water percolation and nutrient leaching can be avoided. Under rainfed condition, crops can better withstand drought condition without moisture stress by using hydrogel.

To reduce transpiration losses, foliar application of nutrient formulations, growth regulators, antitranspirants *etc.* in cotton are being tried by many researchers. The work on biological formulation PPFM (pink pigmented facultative methylobacteria) on stress alleviation in rainfed crops is very limited, at the same time very promising results were documented by scientists. The PPFM, when used as foliar spray it releases osmoprotectants (sugars and alcohols) on the surface of the plants. This matrix helped to protect the plants from desiccation and high temperatures. Whereas, the potassium as spray also enhanced drought tolerance in plants by mitigating harmful effects by increasing translocation and by maintaining water balance. Further, kaolin as an antitranspirant, applied as suspension to plant canopies and forms a film on leaves that increases reflection and reduces absorption of light. Salicylic acid is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in order to mitigating the stress. Keeping this in view, an attempt was made to study impact of *Insitu* soil moisture conservation techniques, Soil conditioner (Pusa hydrogel) with stress management practices on yield, nutrient uptake and post harvest soil nutrient status of cotton under rainfed vertisol

MATERIALS AND METHODS

Field experiments were conducted at Tamil Nadu Agricultural University, Regional Research Station, Aruppukottai during *rabi* season of 2016 and 2017 with the test variety SVPR 2. The experimental site comes under the Southern agro climatic zone of Tamil Nadu and geographically situated at 9º 33' N latitude and 78º 05' E longitude at an altitude of 50 m above mean sea level. North east monsoon season is found to be more favourable in Aruppukottai region since 42 per cent of annual rainfall is being received during this monsoon season. The soil of the experimental fields was medium deep, well drained and vertisol (Type Chromusterts) in texture. The soil low in available nitrogen, low in available phosphorus and high available potassium. All package of practices were carried out as per recommendation of (CPG, 2020).

The experiment was laid out in split plot design, replicated thrice. The main plot treatments consisted of different *insitu* moisture conservation measures *viz.,* Broad Bed and Furrows (I_1), Ridges and Furrows (I_2) and Compartmental Bunding (I_3). The subplot comprises with stress management practices *viz.,* Soil application of pusa hydrogel @ 5 kg/ha ($S\text{-}_1$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) ($S\text{-}_2$) , Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of 5% Kaolin ($S\text{-}_3$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha ($S\text{-}_4$), Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of Salicylic acid 100 ppm ($S\text{-}_5$) and Control ($S\text{-}_6$).

The data analysis for the probability occurrence of 30 years rainfall in a standard week showed that there is a possibility occurrence of getting more than 80 per cent of consecutive dry spell is laid with 45th and 50th standard weeks. So, to avoid stress, foliar spray has given at these standard weeks for the years of study 2016 based on historical rainfall probability analysis by markov chain method. Biometric Observations such as NPK uptake and post-harvest nutrient status nutrient status in soil, Seed cotton yield**,** Dry matter efficiency and Harvest index were also estimated.

The seed cotton yield was obtained from net plot area was shade dried, weighed at each picking and yields of all picking were added and calculated as kg/plot and then expressed in kg/ ha. The data obtained were subjected to statistical analysis and were tested at five per cent level of significance to interpret the treatment differences.

Dry matter efficiency : DME was calculated following the formula suggested by Krishnamurthy (1973)

$$DME = \frac{\text{Seed cotton yield}}{\text{Total dry matter yield}} \times \frac{100}{\text{Duration of genotype in days}}$$

Harvest index

The formula suggested by Arnon (1975) was used to calculate Harvest index (HI).

$$HI = \frac{\text{Seed cotton yield}}{\text{Total biological yield}} \times 100$$

RESULTS AND DISCUSSION

Effect of *insitu* moisture conservation and stress management practices on nutrient uptake of rainfed cotton

Nutrient uptake : Significant differences in NPK uptake of cotton were observed under *insitu* moisture conservation measures and stress management practices during both the years of investigation.

Nitrogen uptake : The analyzed data on nutrient uptake at harvest showed that, nitrogen uptake of rainfed cotton was significantly varied due to *insitu* moisture conservation measures and stress management practices. Among the *insitu* moisture conservation measures, BBF (I_1) was recorded significantly the highest N uptake (67.03 in 2016 and 75.38 kg/ha in 2017) followed by RF (I_2). The lowest uptake of N was recorded (62.04 kg/ha in 2016 and 66.79 kg/ha in 2017) under CB (I_3).

Similarly, among the stress management practices, soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (S_4) recorded significantly the highest N uptake of 72.43 and 82.16 kg/ha respectively during 2016 and 2017. It was followed by soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) (S_2). Significantly lesser N uptake (55.13 and 60.62 kg/ha 2016 and 2017) was accounted in control (S_6) during both the crop seasons.

Phosphorous uptake : It was observed that the P uptake was significantly higher under the *insitu* moisture conservation measure of BBF (I_1) with 16.06 kg/ha in 2016 and 16.13 kg/ha in 2017 followed by RF (I_2) during both the years of

Table 1. Effect of *insitu* moisture conservation and stress management practices on N, P and K uptake (kg/ha) at harvest of rainfed cotton during *rabi* 2016-2017

Treatments	N uptake				P uptake				K uptake			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	62.25	60.56	58.91	**60.57**	14.35	12.59	10.87	**12.60**	69.31	63.10	58.89	**63.77**
S_2	70.85	69.24	67.65	**69.25**	17.44	15.72	14.03	**15.73**	78.67	71.88	67.09	**72.55**
S_3	66.58	66.59	65.59	**66.25**	16.23	14.96	13.71	**14.97**	74.12	69.71	65.37	**69.73**
S_4	75.25	72.09	69.94	**72.43**	19.74	17.68	15.59	**17.67**	85.38	79.59	75.79	**80.25**
S_5	66.86	63.54	60.23	**63.54**	15.86	13.84	11.84	**13.85**	74.91	66.72	58.60	**66.74**
S_6	60.37	55.12	49.89	**55.13**	12.74	11.40	10.02	**11.39**	65.55	58.21	52.86	**58.87**
Mean	**67.03**	**64.52**	**62.04**		**16.06**	**14.37**	**12.68**		**74.66**	**68.20**	**63.10**	
	I	S	I at S	S at I	I	S	I at S	S at I	I	S	I at S	S at I
SEd	0.94	1.43	2.45	2.48	0.26	0.25	0.41	0.35	1.22	1.64	2.86	2.83
CD(p=0.05)	2.41	2.92	NS	NS	1.10	0.51	NS	NS	3.40	3.34	NS	NS

investigation. The lower uptake of P was recorded (12.68 kg/ha in 2016 and 13.19 kg/ha in 2017) under CB (I_3).With regard to stress management practices, soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (S_4) registered the highest P uptake of 17.67 kg/ha and 17.78 kg/ha during 2016 and 2017, respectively, followed by soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) (S_2). Under water stressed condition significantly lesser P uptake values (11.39 and 12.26 kg/ha in 2016 and 2017) were observed in control (S_6) in both the years.

Potassium uptake : Data on K uptake at harvest stage of the crop showed that BBF (I_1) had registered significantly the highest K uptake (74.66 and 78.68 kg/ha) respectively during both 2016 and 2017, followed by RF (I_2). Lesser K uptake was noticed (63.10 kg/ha in 2016 and 65.96 kg/ha in 2017) under CB (I_3). With respect to stress management practices, soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml /ha (S_4) registered significantly superior level of K uptake (80.25 kg /ha in 2016 and 83.86 kg /ha in 2017) followed by soil application of pusa hydrogel @ 5 kg /ha + foliar spray of KCl (1%) (S_2). The lowest K uptake of 58.87 and 61.73 kg/ha in 2016 and 2017 was registered under control (S_6).

The higher nutrient uptake was recorded in BBF. Higher nutrient uptake in BBF system was due to better soil moisture status, proliferated root growth and higher availability of nutrients. The collection of more rain water in the furrows and better use of rainfall and moisture by the crop was achieved by way of utilizing required quantity of available water for solubilizing the soil nutrients from the soil complex and make them more NPK uptake by the crop with help of deeper and root growth obtained in BBF. The increased uptake of N and P under the treatments could be attributed to higher dry matter production apparently because of sustained availability of moisture to the plants.

Higher uptake of nutrients with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha could be attributed to higher moisture level in the root zone, which helped in better utilization of nutrients. Hydrogel maintained the soil moisture status and reduced

Table 2. Effect of *insitu* moisture conservation and stress management practices on N, P and K uptake (kg/ha) at harvest of rainfed cotton during *rabi* 2017-2018

Treatments	N uptake				P uptake				K uptake			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	70.84	66.17	61.53	**66.18**	14.80	13.45	12.19	**13.48**	73.56	66.31	61.06	**66.98**
S_2	79.54	74.61	70.68	**74.94**	17.06	15.48	13.92	**15.49**	82.95	76.72	70.61	**76.76**
S_3	74.54	71.70	68.90	**71.71**	16.06	14.85	13.62	**14.84**	78.80	72.65	68.50	**73.32**
S_4	88.52	82.15	75.81	**82.16**	19.75	17.79	15.81	**17.78**	89.29	83.84	78.46	**83.86**
S_5	75.65	70.77	65.86	**70.76**	15.46	14.08	12.74	**14.09**	80.19	70.51	60.92	**70.54**
S_6	63.20	60.72	57.94	**60.62**	13.64	12.27	10.88	**12.26**	67.26	61.71	56.22	**61.73**
Mean	**75.38**	**71.02**	**66.79**		**16.13**	**14.65**	**13.19**		**78.68**	**71.96**	**65.96**	
	I	S	I at S	S at I	I	S	I at S	S at I	I	S	I at S	S at I
SEd	1.32	1.61	2.86	2.78	0.40	0.24	0.51	0.34	1.89	2.50	4.36	4.34
CD (p=0.05)	3.67	3.28	NS	NS	1.72	0.50	NS	NS	5.05	5.12	NS	NS

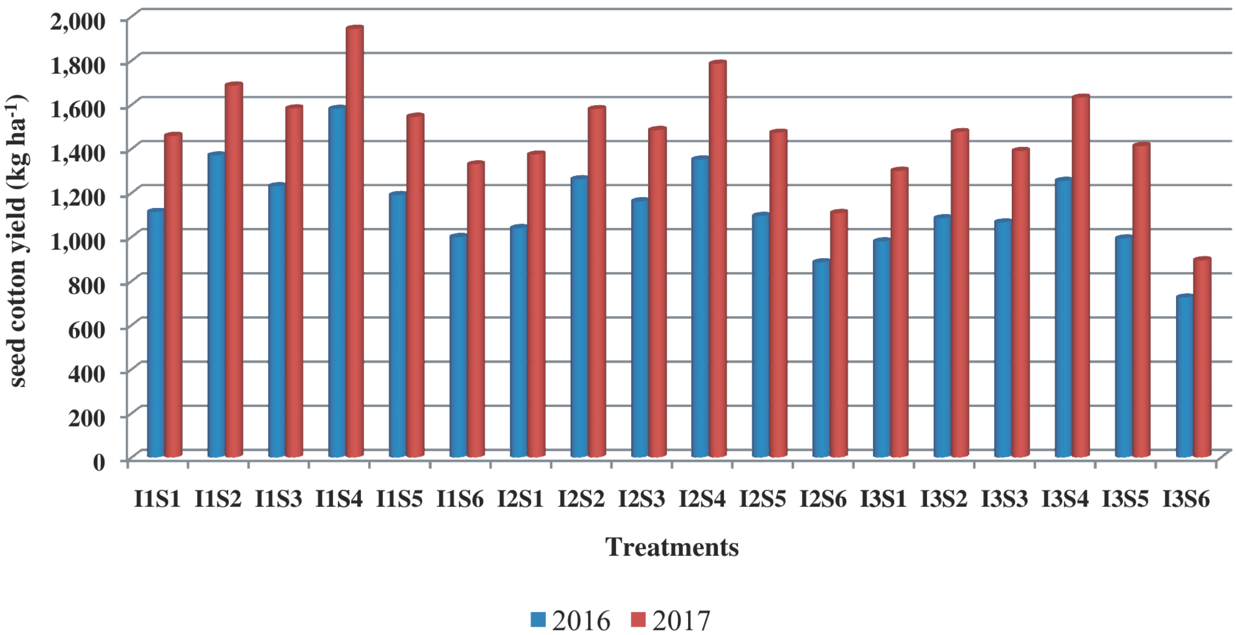

Fig.1. Effect of *insitu* moisture conservation and stress management practices on seed cotton yield (kg/ha) of rainfed cotton during *rabi* 2016 and 2017

Table 3. Effect of *insitu* moisture conservation and stress management practices on available N, P and K (kg/ha) in the post harvest soil sample of rainfed cotton during *rabi* 2016-2017

Treatments	N				P				K			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	161.2	174.2	188.0	**174.5**	13.9	14.5	15.2	**14.5**	255.2	268.1	301.2	**274.8**
S_2	157.1	168.8	182.4	**169.4**	12.3	13.4	14.7	**13.5**	243.5	257.8	274.0	**258.4**
S_3	156.4	170.1	186.1	**170.9**	13.4	14.3	14.9	**14.2**	249.8	262.1	274.1	**262.0**
S_4	145.1	156.2	170.4	**157.2**	11.6	12.7	13.8	**12.7**	230.1	245.3	260.3	**245.2**
S_5	161.7	173.1	188.2	**174.3**	13.7	14.3	15.3	**14.4**	250.2	262.2	288.4	**266.9**
S_6	169.2	185.2	204.1	**186.2**	14.1	15.6	15.9	**15.2**	264.4	283.1	317.2	**288.2**
Mean	**158.5**	**171.3**	**186.5**		**13.2**	**14.1**	**15.0**		**248.7**	**261.8**	**285.0**	
	I	S	I at S	S at I	I	S	I at S	S at I	I	S	I at S	S at I
SEd	3.6	5.4	9.3	9.4	0.3	0.4	0.6	0.6	4.8	6.4	11.2	11.2
CD (p=0.05)	9.9	11.0	NS	NS	0.7	0.6	NS	NS	12.0	12.2	NS	NS

nutrient loss resulting in stronger nutrients uptake by plant. Super absorbent polymers (SAPs) are capable of repeatedly absorbing, retaining and releasing extremely large amounts of water relative to their own weight. Thus, it can improve water conservation in soils, prevent deep percolation and soil nutrient loss, and maximize the use efficiency of fertilizers (Waly *et al.*, 2015). Higher uptake of nutrients under foliar application of PPFM is attributed to higher demand and uptake by the plants owing to higher vegetative growth under this treatment. Similar trend of nutrient uptake was also reported by Sivakumar *et al.,* (2017) (Fig 1).

Post harvest nutrient status of soil : Available N, P and K status of soil after harvest of the crop was significantly influenced by *insitu* moisture conservation measures and stress management practices. After harvest of the crop, the soil samples were collected and analysed for its available nitrogen, phosphorus and potassium status and the results are presented. The *insitu* moisture conservation measures showed a significant variations with respect to post harvest available soil N, P and K. CB (I_3) recorded significantly the higher soil available N, P and K during 2016 (186.5, 15.0, 285.0 kg/ha) and 2017 (163.2, 12.1, 251.3 kg/ha). This was followed RF (I_2). Significantly lowest soil available N, P and K status was recoded in BBF (I_1) in both years of experimentation 2016 (158.5, 13.2, 248.7 kg / ha) and 2017 (134.5, 10.2, 213.5 kg/ha).

With respect to stress management practices treatments, data revealed that a statistically varied soil available soil N, P and K contents. The untreated plot control (S_6) registered the highest soil available N, P and K of 186.2, 15.2, 288.2 and 162.4, 12.3, 255.8 kg/ ha respectively in 2016 and 2017. This was followed by soil application of pusa hydrogel @ 5 kg/ha (S_1). The lowest available N, P and K status (157.2, 12.7, 245.2 in 2016 and 135.3, 9.9, 213.2 kg/ha in 2017) was recorded with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (S_4).

Table 4. Effect of *insitu* moisture conservation and stress management practices on available N, P and K (kg/ha) in the post-harvest soil sample of rainfed cotton during *rabi* 2017-2018

Treatments	N				P				K			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	132.1	154.2	167.0	**151.1**	10.4	11.4	12.4	**11.4**	215.2	239.1	253.2	**235.8**
S_2	135.4	147.1	160.2	**147.6**	9.7	10.7	11.9	**10.8**	206.4	231.4	246.0	**227.9**
S_3	132.2	149.2	165.3	**148.9**	10.2	11.3	12.3	**11.3**	213.1	234.5	253.0	**233.5**
S_4	123.3	135.4	147.2	**135.3**	9.3	10.0	10.4	**9.9**	201.3	212.0	226.2	**213.2**
S_5	134.4	153.1	164.1	**150.5**	10.1	11.3	12.4	**11.3**	214.2	238.7	252.4	**235.1**
S_6	149.7	162.4	175.2	**162.4**	11.7	12.2	12.9	**12.3**	231.0	259.2	277.1	**255.8**
Mean	**134.5**	**150.2**	**163.2**		**10.2**	**11.2**	**12.1**		**213.5**	**235.8**	**251.3**	
	I	S	I at S	S at I	I	S	I at S	S at I	I	S	I at S	S at I
SEd	3.6	5.5	9.4	9.5	0.3	0.4	0.6	0.6	5.4	7.4	12.9	12.9
CD(p=0.05)	10.1	11.2	NS	NS	0.8	0.7	NS	NS	14.0	14.2	NS	NS

Effect of *insitu* moisture conservation and stress management practices on seed cotton yield : The total seed cotton yield is the function of combined effect of entire yield components exposed under particular set of environmental conditions. The results on the seed cotton yield showed that the various moisture conservation measures and stress management practices significantly influenced the seed cotton yield. In general, irrespective of treatments, seed cotton yield was found to be higher in 2017 than 2016.

With regard to the *insitu* moisture conservation measure, BBF (I_1) recorded

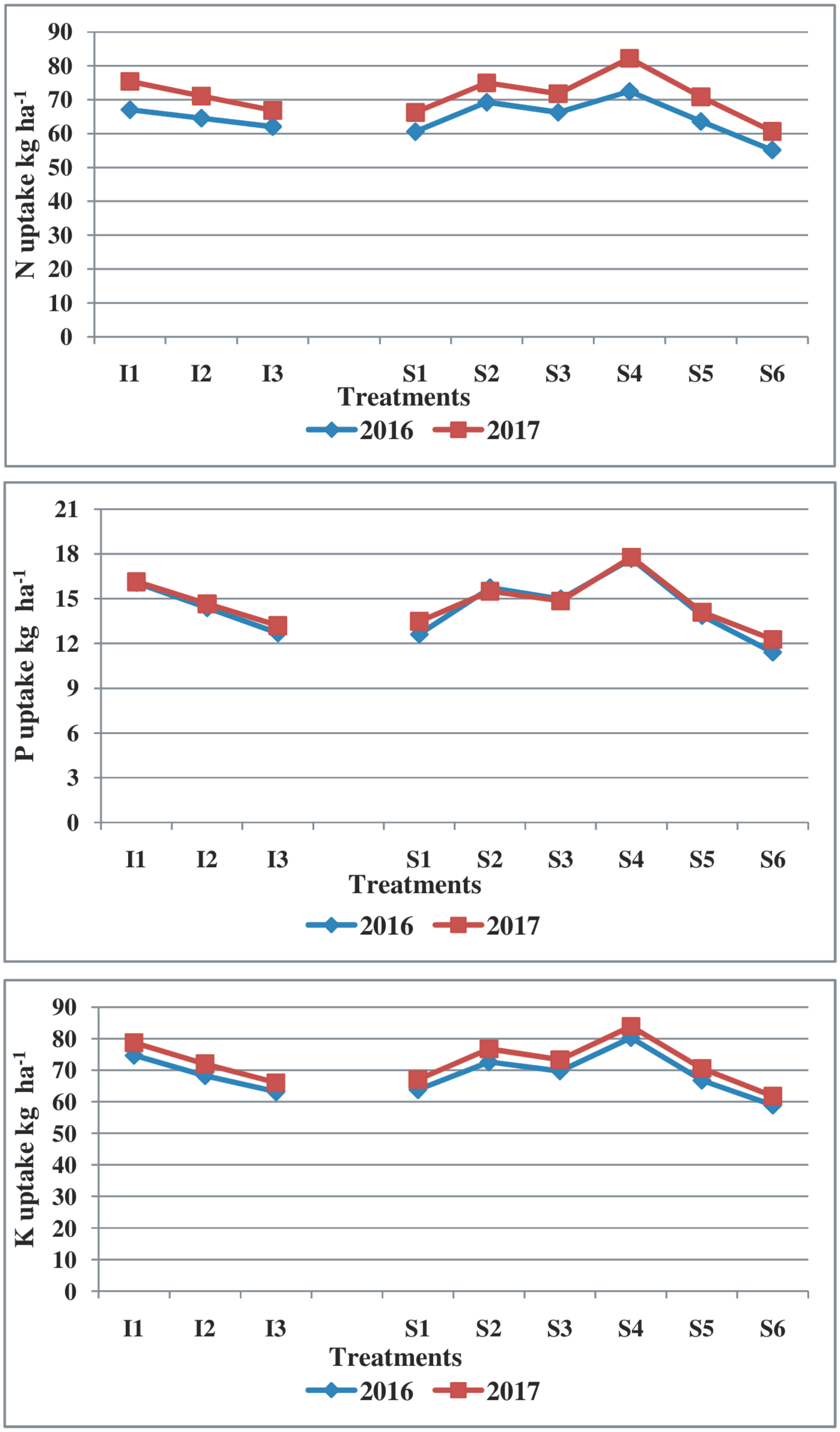

Fig.2. Effect of *insitu* moisture conservation and stress management practices on N, P and K uptake (kg/ha) at harvest of rainfed cotton during *rabi* 2016 and 2017

significantly higher seed cotton yield of 1246 kg/ha in 2016 and 1590 kg/ha in 2017, followed by RF (I_2). The lower seed cotton yield was recorded in CB (I_3) with 1016 kg/ha in 2016 and 1350 kg/ha in 2017. Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml ha^{-1} (S_4), which registered the higher seed cotton yield of 1394 and 1786 kg/ha during 2016 and 2017, respectively. This was followed by soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) (S_2) with 1,238 and 1,580 kg/ha of seed cotton during 2016 and 2017, respectively. The lower seed cotton yield was recorded under control (S_6) with 869 kg/ha (2016) and 1,109 kg/ha (2017).

Interaction between *insitu* moisture conservation and stress management practices was found significant. The combination of BBF with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (I_1S_4) recorded highest seed cotton yield of 1580 and 1943 kg/ha in 2016 and 2017, respectively. The lowest seed cotton yield of 724 and 893 kg/ha was recorded under the combination of CB with control (I_1S_6) in 2016 and 2017, respectively.

Yield is contributed by different yield components and any influence made by extraneous factor, will alter the yield significantly. In the present study, increased seed cotton yield could be attributed to better crop growth and yield components due to consistent soil moisture availability due to combined influence of BBF, soil conditioner and foliar application of PPFM. The broad bed furrow system significantly influenced the seed cotton yield as compared to other land configuration. BBF recorded significantly higher seed cotton yield of 1,246 kg/ha (2016) and 1,590 kg/ha (2017) which was 23 per cent (2016) and 19 per cent (2017) higher as compared to compartmental bunding. Increment in seed cotton yield was due to more soil moisture availability at the root zone which favoured better crop growth, more nutrient uptake and higher translocation leading to production of larger leaf area index which was responsible for harvesting more solar energy. This coupled with higher stomatal conductance and transpiration rate resulted accumulation of more dry matter and yield components and ultimately the seed cotton yield. This is in

Table 5. Effect of *insitu* moisture conservation and stress management practices on seed cotton yield (kg/ha) under rainfed condition during *rabi* 2016 and 2017

Treatments	*Rabi* 2016				*Rabi* 2017			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	1,112	1,039	979	**1,043**	1,457	1,373	1,299	**1,376**
S_2	1,369	1,260	1,084	**1,238**	1,686	1,579	1,475	**1,580**
S_3	1,229	1,160	1,065	**1,151**	1,582	1,484	1,389	**1,485**
S_4	1,580	1,350	1,253	**1,394**	1,943	1,785	1,631	**1,786**
S_5	1,189	1,094	992	**1,092**	1,544	1,472	1,411	**1,476**
S_6	998	884	724	**869**	1,328	1,107	893	**1,109**
Mean	**1,246**	**1,131**	**1,016**		**1,590**	**1,467**	**1,350**	
	I	S	I at S	S at I	I	S	I at S	S at I
S.Ed	33	33	61	57	32	48	71	68
CD (p=0.05)	90	67	138	116	117	100	178	141

similarity with the findings of Reddy *et al.*, (2015).

Higher seed cotton yield was realized with complementary alliance of *insitu* moisture conservation measures with stress management practices in the present study. Significant influence by stress management practices also recorded with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha, which registered higher seed cotton yield of 1,394 and 1,786 kg/ha during 2016 and 2017, respectively.

The increased seed cotton yield under soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha was 60 per cent during 2016 and 61 per cent in 2017 over control. This may be due to increase in growth and yield related attributes. Further it could be because of sufficient availability of soil moisture due to super absorbent polymer under water stress condition, which in turn lead to better translocation of water, nutrients and photo assimilates and finally better plant development under water stress condition. However during stress, presence of photosynthetically active leaf area due to moisture availability by SAP exhibited more chlorophyll meter readings was also positively correlated to yield.

The present study revealed that foliar application of PPFM when combined with soil application of pusa hydrogel resulted in enhanced seed cotton yield. The enhancement of yield was associated with increased bolls / plant through improved boll retention. Significant increase in seed cotton yield with the application of PPFM was reported by Srinivasan *et al.,* (2017). The beneficial influence by PPFM may be attributed to several factors such as, release of growth promoting substances like auxins, particularly indole-3-acetic acid (IAA) and indole-3-pyruvic acid, zeatin, zeatin riboside, proliferation of beneficial organisms in the phylosphere and reacted cytokinins by methylotrophs were enhance the plant growth of crops due to vegetative growth of the plant attributed to increase in the yield of a crop. And hence, it could be concluded that foliar application of PPFM favourably influenced the seed cotton yield.

The combination of BBF with soil application of pusa hydrogel @ 5 kg/ha + foliar

Table 6. Effect of *insitu* moisture conservation and stress management practices on harvest index of rainfed cotton

Treatments	*Rabi* 2016-2017				*Rabi* 2017-2018			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	0.25	0.24	0.23	**0.24**	0.29	0.29	0.28	**0.29**
S_2	0.28	0.28	0.25	**0.27**	0.32	0.29	0.29	**0.30**
S_3	0.26	0.26	0.26	**0.26**	0.29	0.29	0.28	**0.29**
S_4	0.31	0.27	0.26	**0.28**	0.33	0.32	0.32	**0.32**
S_5	0.26	0.25	0.24	**0.25**	0.29	0.28	0.28	**0.28**
S_6	0.23	0.20	0.19	**0.21**	0.28	0.25	0.22	**0.25**
Mean	**0.27**	**0.25**	**0.24**		**0.30**	**0.28**	**0.28**	
	I	S	I at S	S at I	I	S	I at S	S at I
SEd	0.005	0.006	0.010	0.010	0.005	0.008	0.011	0.011
CD (p=0.05)	0.013	0.011	NS	NS	0.013	0.016	NS	NS

Table 7. Effect of *insitu* moisture conservation and stress management practices on dry matter efficiency of rainfed cotton

Treatments	*Rabi* 2016-2017				*Rabi* 2017-2018			
	I_1	I_2	I_3	**Mean**	I_1	I_2	I_3	**Mean**
S_1	0.191	0.190	0.190	**0.190**	0.164	0.158	0.151	**0.158**
S_2	0.212	0.197	0.192	**0.200**	0.189	0.186	0.167	**0.181**
S_3	0.195	0.193	0.189	**0.192**	0.176	0.175	0.175	**0.175**
S_4	0.222	0.216	0.211	**0.216**	0.204	0.182	0.176	**0.187**
S_5	0.191	0.190	0.188	**0.190**	0.172	0.168	0.162	**0.167**
S_6	0.187	0.169	0.148	**0.168**	0.154	0.134	0.129	**0.139**
Mean	**0.200**	**0.193**	**0.186**		**0.177**	**0.167**	**0.160**	
	I	S	I at S	S at I	I	S	I at S	S at I
SEd	0.03	0.005	0.008	0.007	0.005	0.005	0.008	0.007
CD(p=0.05)	0.012	0.011	NS	NS	0.018	0.011	NS	NS

spray of PPFM @ 500 ml/ha recorded higher yield (Fig. 2) with an increase of 133 and 150 per cent during 2016 and 2017, respectively than the compartmental bunding with control (Fig 2).

Harvest index : Harvest index of rainfed cotton was significantly influenced by various moisture conservation measures, among the treatments, BBF (I_1) recorded highest harvest index of 0.27 and 0.30 in 2016 and 2017 followed by RF (I_2). Harvest index was found be less under CB (I_3) with 0.24 and 0.28 during 2016 and 2017, respectively. Stress management practices significantly influenced the harvest index during both the years of experimentation. Soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (S_4) recorded higher harvest index of 0.28 and 0.32, respectively of 2016 and 2017. It was comparable with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) (S_2). Lower harvest index was recorded in control (S_6) with 0.21 in 2016 and 0.25 in 2017.

Dry matter efficiency : The moisture conservation measures had a significant influence on dry matter efficiency. Higher dry matter efficiency was recorded under BBF (I_1) with 0.200 and 0.177 during 2016 and 2017, respectively. In both the years of experimentation, compartmental bunding (I_3) produced lower dry matter efficiency. In the case of the stress management practices, soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha (S_4) recorded significantly higher dry matter efficiency of 0.216 and 0.187 during 2016 and 2017, respectively. This was found to be comparable with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of KCl (1%) (S_2) during both the seasons. The dry matter efficiency was found to be lesser under recorded in control (S_6) with 0.168 in 2016 and 0.139 in 2017.

CONCLUSION

Broad bed and furrows combined with foliar application of PPFM spray at 500 ml/ha was obtained significantly highest nutrients uptake (N, P and K) and seed cotton yield followed by ridges and furrows combined with foliar application of PPFM spray at 500 ml/ha under rainfed areas. The higher values indicate that the moisture conservation and stress management practices improve growth rate performance it leads to more yield potential of rainfed cotton. Broad bed and furrows combined with soil application of pusa hydrogel @ 5 kg/ha + foliar spray of PPFM @ 500 ml/ha during the stress period was found to be the best agronomic management practice in order to enhance yield and nutrient uptake in cotton under rainfed vertisols.

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