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Impact of Land Configurations and Integrated Nutrient Management Practices on Root Properties, Yield, NPK uptake of *Bt* cotton and Fertility Status of Soil

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***Abstract*:** A field experiment was carried out to find the impact of different land configurations and integrated nutrient management practices on root properties, yield, NPK uptake of *Bt* cotton and fertility status of the soil at Professor Jayashankar Telangana State Agricultural University, Hyderabad. The yield attributes (bolls per plant and boll weight) and seed cotton yield were significantly higher with BBF laid with poly mulch in addition with application of 100% RDF + 25% RDN through organics (pressmud or FYM), which was comparable to Broad Bed Furrow laid with poly mulch and application of 125% RDF through inorganics. Similarly, among the land configuration treatments, Poly mulch on broad bed has recorded higher root yield, root volume, NPK uptake and post-harvest status of soil such as organic carbon (%) and available soil NPK respectively. Application of 100% RDF + 25 % RDN through Pressmud has recorded highest yield and yield attributes, root weight and volume, NPK uptake and available NPK status in the soil which was at par with 100% RDF + FYM equivalent to 25 % RDN and 125% RDF alone among the nutrient management practices. Based on the results, poly mulch on broad bed in combination with either pressmud or FYM or application of 125% RDF alone can be well recommended to farmers of Telangana.

***Keywords*:** Bt cotton, Poly mulch, Ridge and furrow, Broad bed and furrow, FYM and pressmud, INM and field water use efficiency

Cotton is a member of the Malvaceae family and is primarily farmed in tropical and subtropical regions. The objective of cotton development programmes around the world has always been to combine high yield and high-quality fiber in order to meet the needs of growers and industry (Mudhalvan et al 2021). Fertilizer makes up 20–30% of the cost of producing cotton, which has high nutritional requirements. However, there isn't much information in the literature about cotton's dietary needs, particularly for recently developed varieties. To achieve high yields, lower production costs per ton, and boost the financial viability of the production system, cotton must receive adequate nutrition (Vieira et al 2018).

Currently India has topped in area with 11.88 m ha^{-1} covering 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^{-1} (Directorate of Cotton Development, 2017). The productivity of cotton is significantly lower (568 kg ha^{-1}) as compared to the four major cotton growing countries *i.e.,* China (1300 kg ha^{-1}), USA (900 kg ha^{-1}), Pakistan (700 kg ha^{-1}) and Brazil (673 kg ha^{-1}).

Black soils are ideal for growing cotton, yet in our nation, more than 65% of cotton is cultivated on red soil. Along with assuring superior stand, establishment, uniform growth, fertilizer use efficiency, and yield under rainfed conditions, correct land configuration according to the soil type also helps to conserve soil moisture effectively (Kumari et al 2018). In dryland agriculture, the evapotranspiration needs of crops are not only not met by the amount of rainfall, but also by how it is distributed. Moisture conservation is the main issue in dry land farming. In situ rainwater conservation is therefore necessary. For the purpose of achieving sustainable yields, effective rain water management and in-situ moisture conservation, such as opening furrows, intercropping, mulching, etc., are essential (Gokhale et al 2012). Mulch specifically prevented the movement of water vapor from the soil surface to the microclimate, which reduced the direct evaporative loss of soil water and enhanced the soil's availability to the crops (Xie et al 2006, Fuchs and Hadas 2011). Utilizing plastic mulch has demonstrated water savings in cotton of between 40 and 50 percent (Nalayani et al 2009).

Farmers are not using fertilizers at the recommended rates, which causes an imbalance between the supply of nutrients and the demand from crops (Karthiket al 2022, Dhaker et al 2022). One of the main causes of low cotton output is the unbalanced use of fertilizers, which has led to soil productivity issues and micronutrient shortages. To achieve higher yields and maintain soil health, an integrated application of chemical fertilizers and organic manures is required. Due to the low or nonexistent maintenance of the cattle population on the farm, organic sources with high nutrient content, such as Pressmud, may be a better option given the limited availability of FYM (Ghulam et al 2012).In light of the aforementioned facts, this study was conducted to determine the effects of various soil moisture conservation strategies and integrated nutrient management approaches on the root characteristics, productivity, NPK uptake of *Bt cotton* and post-harvest fertility status of red soil in Telangana.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* 2015 and 2016 at College farm, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad situated at an altitude of 542 m above mean sea level at 17°19' N latitude, 78°23' E longitude under rainfed conditions. The soil of the experimental site was sandy loam with soil pH of 7.33, low available N (182 kg ha^{-1}), medium in P_2O_5 (46.8 kg ha^{-1}) and high in K_2O (432 kg ha^{-1}). The experiment was laid out in strip plot design with three replications. The size of gross and net plots were7.2 m x 5.4 m and 5.4 m x 4.2 m respectively. There were twenty treatments with combinations of four *in-situ* moisture conservation practices (main plots)*viz.,* flat method (M_1), ridge and furrow (M_2), BBF (M_3) and poly mulch on BBF (M_4) as main plots and five integrated nutrient management (INM) practices as sub plots i.e., Farmer's practice (S_1), 100% recommended dose of fertilizers (RDF, S_2), 125% RDF (S_3), 100% RDF along with 25% N through FYM (S_4) and 100% RDF along with 25% RDN through press mud (S_5). Bt hybrid Neeraja BT-II seeds were dibbled @ 1 seed $hill^{-1}$ on 7th July during 2015 and 2nd July during 2016. The recommended dose of fertilizers to cotton in Telangana state was 150:60:60 NPK kg ha^{-1}.Entire P fertilizer was applied as basal and N and K applied at 20, 40, 60 and 80 days after sowing (DAS) in equal splits. In integrated nutrient management treatments (S_4sand S_5), 25 per cent nitrogen was applied through organic manures as basal and remaining as that of recommended dose of fertilizers (100% RDF). Farmers practice of nutrient management was decided after survey of nutrient management in 30 cotton growing farmers fields in Telangana. Farmers are applying 50 kg of DAP at 20-25 DAS, 50 kg of 14-35-14 at 40-45 DAS, 50 kg of urea and 25 kg of muriate of potash at 60-65 DAS, 75 kg urea and 25 kg potash at 80-100 DAS. Based on the above, farmers practice of nutrient management was 3.75 t FYM ha^{-1}, 184-101-92kg N, $P_2O_5$and K_2O ha^{-1}followed.

Pressmud contains 1.92and 2.24 percent nitrogen during 2015 and 2016. FYM contains 0.49 and0.72% during 2015 and 2016. After laying land configurations, during 2015, 1953 kg of pressmud and 7653 kg of FYM were applied in S_5 and S_4 treatment plots. During 2016, 1674 kg of pressmud and 5208 kg of FYM were applied in S_5 and S_4 treatments. In M_1 treatment, simple flat bed method of sowing was imposed without any soil moisture conservation treatments as check. In M_2 treatment, ridges and furrows were laid at 90 cm apart respectively. While in M_3 sand M_4 broad bed and furrow treatment, beds of 120 cm width and furrows of 60 cm were laid. In M_4 treatment**,** polythene mulch with black (upper) and grey (bottom) having 25 μ thickness was laid before sowing of the crop on the raised (broad) beds (120cm). Before laying the film, small circular holes were made as per the intra row spacing (60 cm) of the crop and the sheet was spread on the raised bed. After that, the sides of the polythene film were covered within the soil. Under all the treatments, sowing was done by adopting intra row spacing of 60 cm, thus maintained uniform plant population (18,519 plants ha^{-1}). A total rainfall of 375.3 mm was received in 27 rainy days during 2015-16 and 741.1 mm in 37 rainy days during 2016-17, against the decennial average of 616 mm received in 37 rainy days. The crop was sprayed with monocrotophos @ 1 ml l^{-1} against aphids and bollworms and drenching of carbendazim @ 1g l^{-1} of water against wilt. The crop was finally terminated on 10th December during 2015 and 6th December during 2016. Statistical analysis of the data of various yield attributes, root properties, yield, NPK uptake studied were carried out

RESULTS AND DISCUSSION

All the parameters like the number of bolls produced per plant, boll weight, cotton seed and stalk yield, root weight, root volume, NPK uptake of cotton was significantly affected by moisture conservation practices and integrated nutrient management practices during both the years of study. The interaction effect was also significant among all parameters.

Number of bolls $plant^{-1}$: Number of bolls $plant^{-1}$ were significantly higher in poly mulch on broad bed (M_4) (28.7). Pooled data analysis indicated that, the mean increase in number of bolls per plant under poly mulch on broad bed (28.7) was 38.6, 21.6 and 12.5 per cent over flat bed (M_1), broad bed sand furrow (M_3) and ridge sand furrow (M_2) methods, respectively (Table 1). The increase in the number of bolls $plant^{-1}$in mulched plot was probably associated with the conservation of moisture and favorable micro climate which in turn provided a favorable conditions towards higher dry matter accumulation and greater number of leaves and fruit bearing nodes as compared to the rest of the moisture conservation treatments. Ridge and furrow (M_2) method was on par with M_4 and recorded significantly higher number of bolls as compared to broad bed sand furrow and flatbed methods during both the years of experimentation. Pooled data analysis indicated that, the mean increase in number of bolls under ridge sand furrow (25.5) was 23.1 and 8.0 per cent over flat bed and broad bed and furrow methods. This might be due to the higher amount of moisture conserved in ridge and furrow as compared to flat bed sowing and broad bed methods. Broad bed and furrow method recorded significantly higher number of bolls compared to flat bed method during both the years. Pooled data analysis indicated that, the mean yield advantage under broad bed sand furrow (23.6) was 14.0 per cent over flat bed method. Increase in the number of sympodial branches and squares per plant lead to the increase in the number of bolls per plant. Significantly higher number of bolls were recorded in S_5 (100% RDF + 25% RDN through pressmud). Pressmud after decomposition releases major and micro nutrients, which become available throughout crop growth period that lead to more number of bolls per plant.S_5 treatment was on par with (S_4) 100% RDF + 25% RDN through FYM (26.0). The higher number of bolls in combined application of 100 % RDF and 25% RDN through FYM could be due to continuous supply of nutrients from FYM to the plant. Inbuilt resistance to boll worms and early maturing character was observed in case of *Bt* hybrid which helped to retain more number of bolls by avoiding its exposure to unfavourable weather condition during peak period of growth that may commence probably during later stages. Hence, application of 100% RDF along with 25% RDN through FYM showed marked effect on number of bolls per plant. These results are in conformation with the findings of Jagdish Kumar and Yadav (2010). Application of 100% RDF + 25% RDN through FYM (S_4) was on par with (S_3) 125% RDF (25.4) followed by (S_1) farmers' practice (23.3) and (S_2) 100% RDF (21.8). The application of 125% RDF over 100% RDF resulted in efficient translocation of photosynthates due to adequate amount of available nutrients that favored higher number of bolls and boll weight. Singh et al (2003) reported that 125% RDF resulted in significantly higher yield as compared with RDF alone. Interaction between soil moisture conservation practices and integrated nutrient management practices was found to be significant. Significantly higher number of bolls were recorded with application of poly mulch on broad bed and application of 100% RDF along with 25% RDN through pressmud (M_4S_5) recorded significantly highest mean number of bolls (30.3) and poly mulch on broad bed and application of 100% RDF along with 25% RDN through FYM (30.1). M_4S_4 treatment was in par with poly mulch on broad bed and application of 125% RDF (M_4S_3) indicating that poly mulch on broad bed was comparatively more effective when RDF applied along with either pressmud or FYM. More retention of soil moisture and continuous supply of nutrients in these treatments resulted in higher number of bolls in *Bt* cotton hybrid and it might have got the full advantage of available soil moisture and nutrient management during boll development stage.

Boll weight (g): Perusal of data indicated significant effect of moisture conservation treatments on boll weight of *Bt* cotton hybrid. During both the years, poly mulch on broad bed method recorded significantly higher boll weight (6.0 g) compared to rest of the moisture conservation treatments (Table 1). The poly mulched cotton had significantly produced heavier bolls against other land configurations. This might be due to better partitioning of assimilates under mulching, due to conservation of soil moisture, restricted weed growth and increased soil temperature under mulched treatment. The next best treatment was ridge and furrow method (M_2) which recorded significantly higher boll weight (5.6 g) as compared to broad bed sand furrow and flatbed methods during both the years. This might be due to the reason that ridge and furrow reduces the runoff and thus

Table 1. Effect of land configurations and nutrient management practices on bolls per plant and boll weight of Bt cotton (Pooled data)

Treatments	No. of bolls per plant						Boll weight (g)					
	S_1	S_2	S_3	S_4	S_5	Mean	S_1	S_2	S_3	S_4	S_5	Mean
M_1 – Flatbed (control)	19.7	17.6	21.3	22.0	23.0	20.7	4.7	4.3	4.8	4.8	4.6	4.7
M_2 – Ridge sand furrow	24.1	22.9	26.2	27.0	27.5	25.5	5.2	5.0	5.7	5.8	5.9	5.6
M_3 – BBF	22.0	20.9	24.3	25.0	25.7	23.6	4.9	4.8	5.2	5.4	5.9	5.2
M_4 – Poly mulch on BBF	27.5	26.0	29.9	30.1	30.3	28.7	5.9	5.5	6.0	6.0	6.2	6.0
Mean	23.3	21.8	25.4	26.0	26.6	24.6	5.2	4.9	5.5	5.5	5.6	5.3
C.D at 5%		1.4	0.7	0.4	1.5			0.3	0.3	0.4	0.5	
CV		7.5						7.9				

Sub treatments (S) S_1: Farmers practice, S_2: 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN , S_5: 100% RDF + Pressmud equivalent to 25% RDN provides more opportunity time for infiltration. Adequate soil moisture conservation through opening of furrow after each row resulted in higher boll weight and more seed cotton yield plant^{-1} especially in rainfed cotton zone. (Narkhede et al 2015). Pooled data analysis indicated that broad bed sand furrow method (M_3) recorded significantly higher boll weight (5.2 g) compared to flatbed method. Lower boll weight under flat bed method might be due to lower availability of water and nutrients, thereby reduced LAI and crop dry matter that lead to poor portioning of resource to sink (bolls). The boll weight of *Bt* cotton hybrid was significantly affected by different integrated nutrient management practices. Significantly higher boll weight (5.6 g) was recorded with application of (S_5) 100% RDF + 25% RDN through pressmud treatment. This could be due to increased availability of N, P, K, Ca, Mg and S through pressmud application. Kalaivanam and Omar Hattab (2008) reported that addition of pressmud increased the availability of nutrients and their uptake in rice and wheat crops. S_5 treatment was on par with 100% RDF + 25 % RDN through FYM (5.5 g) and 125% RDF (5.5 g). Significantly higher boll weight in treatments consisting of combined application of RDF and organics could be due to favorable effect in improving soil physical properties and better nutrient supply throughout the crop growth. Hence, application of RDF along with pressmud or FYM showed marked effect on yield attributes of cotton. Higher boll weight might be due to production of higher number of monopodial and sympodial branches and thereby larger bolls that lead to higher accumulation of photosynthates in reproductive parts. Similar finding in cotton was earlier reported by Mehta et al (2009). The treatment consisting of application of 125% RDF was comparable with (S_1) Farmers practice (5.2 g) and S_1 was in turn on par with (S_2) 100% RDF (4.9 g). Higher boll weight under 125 % RDF could be ascribed to the improved LAI and drymatter production. Thus, higher photosynthetic activity with adequate nitrogen fertilization enabled the plant to accumulate more drymatter and greater translocation of photosynthates to the developing boll resulting in higher number of seeds per boll that reflected in larger bolls. Interaction between treatment combination involving poly mulch on broad bed and application of RDF along with 25 % RDN through pressmud (M_4S_5) recorded significantly highest boll weight (6.2 g). This treatment was on par with (M_4S_4) poly mulch on broad bed and application of RDF along with 25 % RDN through FYM (6.0 g). These two treatments were in turn on par with M_4S_3, M_4S_1, M_2S_5 and M_3S_5 indicating that poly mulch on broad bed was on par with broad bed and ridge and furrow method of sowing along with 100 % RDF + pressmud equivalent to 25% RDN.

Seed cotton yield (kg ha^{-1}): There was significant effect of moisture conservation treatments on seed cotton yield. During both the years, poly mulch on broad bed method was superior over other treatments and recorded significantly higher seed cotton yield (Table 2). Pooled data analysis indicated that, the mean yield advantage under poly mulch on broad bed (2183 kg ha^{-1}) was to the tune of 31.34, 19.74 and 8.66 per cent respectively over flat bed, broad bed sand furrow and ridge sand furrow methods. The highest yield under poly mulch on broad bed method was due to conservation of soil moisture, restricted weed growth and increase in the soil temperature there by preventing the loss of nutrients and favorable soil micro climate congenial for better growth and development of the crop. Increasing the number of monopodial and sympodial branches per plant lead to the increase in the number of bolls per plant consequently higher seed cotton yield per plant. The present results are in conformity with Hugar and Halemani (2010) who also reported improved seed cotton yield under polyethylene mulch to the extent of 11 to 27 per cent as compared to no mulch. The treatment Poly mulch on broad bed was followed by ridge and furrow, that recorded significantly higher seed cotton yield over broad bed sand furrow and flat bed methods during both the years. Pooled data analysis indicated that, the mean yield advantage under

Table 2. Effect of land configurations and nutrient management practices on Seed cotton yield (kg ha^{-1}) of Bt cotton (Pooled data)

Treatments	S_1	S_2	S_3	S_4	S_5	Mean
M_1 – Flatbed (Control)	1566	1447	1695	1758	1843	1662
M_2 – Ridge sand furrow	1871	1779	2076	2125	2195	2009
M_3 – BBF	1687	1590	1898	1938	2004	1823
M_4 – Poly mulch on BBF	2018	1888	2293	2346	2370	2183
Mean	1785	1676	1990	2042	2103	1919
C.D at 5%		89	68	53	100	
CV		7.2				

ridge sand furrow (2009 kg ha^{-1}) was to the extent of 20.87 and 10.2 per cent over flat bed and broad bed sand furrow methods. This might be due to the reduced runoff under ridge and furrow method that provided more opportunity time for infiltration. Ambikaet al(2017) reported that ridge and furrow method of planting recorded significantly higher leaf area, total drymatter production, seed cotton yield and harvest index over flatbed. Broad bed sand furrow method recorded significantly higher seed cotton yield compared to flat bed method during both the years. The mean yield advantage under broad bed sand furrow (1823 kg ha^{-1}) was 9.68 per cent over flat bed method. The increased seed cotton yield was due to improved yield components i.e., number of squares, number of bolls plant^{-1}, mean boll weight and seed cotton yield plant^{-1} (Table 1 and 2). In broad bed and furrow system, there was an advantage of draining excess water around the plant during high rainfall events such as, at 60- 90 DAS stage during the year 2015 or 16. BBF aids in better moisture conservation over flat bed method during moisture stress period during boll development stage. The lower yield in flatbed method was due to reduced number of squares, number of bolls plant^{-1}, mean boll weight and seed cotton yield plant^{-1}. The yield of *Bt* cotton was significantly influenced by integrated nutrient management practices. Significantly higher seed cotton yield (2103 kg ha^{-1}) was recorded in 100% RDF + 25% RDN through pressmud (S_5) treatment. The higher seed cotton yield with different INM practices may be attributed to the various yield components *viz*., number of good and bad opened bolls per plant, number of squares per plant, number of bolls per plant, boll weight. The use of organic manures like pressmud or FYM increases the microbial activity which in turn helps in solubilization of nutrients making them more available to plants. Kumar et al (2017) reported that application of 20 t/ha pressmud and addition of NPK equivalent to 75% of recommended dose to each crop through fertilizers were found to be beneficial and resulted 21-43% higher crop yield. Sugarcane filter cake or pressmud is valued as a soil amendment and an important source of crop nutrients. It is a source of replenishing nutrients in the soil either alone or in combination with fertilizer to subsidize the input costs. Similar results were earlier reported by Raut et al (2008). The treatment (S_4) consisting of application of 100% RDF + 25% RDN through FYM (2042 kg ha^{-1}) was at par with S_5 treatment. The higher seed cotton yield in treatments consisting of integration of organics and inorganics was due to their beneficial effect in improving soil physical characters and supply of nutrients throughout the crop growth period. Hence, application of RDF along with pressmud or FYM showed marked effect on seed cotton yield. This could be attributed to the effect of applied fertilizer and mineralization of organic sources or through solublization of the nutrients from the native sources during the process of decomposition. These results are in conformity with those of Solunke et al (2011) and Tayade et al (2012). Application of 100% RDF + 25% RDN through FYM (S_4) was in turn on par with 125% RDF (1990 kg ha^{-1}) followed by (S_1) Farmers practice (1785 kg ha^{-1}) and (S_2) 100% RDF (1676 kg ha^{-1}). Higher seed cotton yield under 125% RDF over 100% RDF was due to the efficient translocation of photosynthates due to adequate amount of available nutrients that favored higher number of bolls and boll weight thus reflecting in higher seed cotton yield. These results are in accordance with those of Kalaichelvi (2009) who reported significantly higher yields with125% RDF as compared to RDF alone.

Interaction between treatment combination involving poly mulch on broad bed and application of 100% RDF along with 25% RDN through pressmud (M_4S_5) recorded significantly higher (63.8 %) mean seed cotton yield (2370 kg ha^{-1}) over flat bed along with application of 100% RDF (M_1S_2). This treatment was comparable with (M_4S_4) poly mulch on broad bed and application of 100% RDF along with 25% RDN through FYM (2346 kg ha^{-1}). M_4S_5 and M_4S_4 treatments were in turn on par with poly mulch on broad bed and application of 125% RDF (M_4S_3) indicating that poly mulch on broad bed was more effective when RDF applied along with pressmud or FYM or 125% RDF alone. Increased seed cotton yield under broad bed and furrow with poly mulch was due to the sufficient soil moisture in the root zone and minimized evaporation loss due to mulching. The extended retention of moisture lead to higher uptake of nutrients for proper growth and development of plant which resulted in higher yield as compared to control. Organic manures increased organic matter and improved the physical, chemical and biological properties of the soil after decomposition, thus improved plant growth and development reflecting in higher yields. These results are in accordance with those of Patel et al (2015), who reported that increase in the seed cotton yield with application of pressmud, FYM and higher fertilizer (125% RDF) might be due to significantly higher growth parameters and higher drymatter accumulation in reproductive parts. Utilization of more photosynthates for the nourishment to bolls favoring reproductive growth could be the key physiological phenomenon in *Bt* cotton that resulted into more seed cotton yield.

Root Properties

Root weight (g): There was significant effect of moisture conservation treatments on root weight. Poly mulch on broad bed method recorded significantly higher root weight during both the years as compared to rest of the moisture conservation treatments (Fig. 1). The higher root weight under poly mulch on broad bed was 12.4 g and was 37.7, 19.2 and 12.7 per cent over flat bed, broad bed sand furrow and ridge sand furrow methods respectively. Increased root weight in poly mulch was due to increased root length of primary and secondary roots. The enhanced root growth under mulching might be due to enhanced root proliferation due to higher moisture and moderate temperature. The next best treatment was ridge and furrow, which recorded significantly higher root weight as compared to broad bed sand furrow and flat bed methods during both the years. Pooled data analysis indicated that, the mean increase in root weight under ridge sand furrow was 11.0 g and was 22.2 and 5.76 per cent higher over flat bed and broad bed sand furrow methods. This might be due to proper drainage of excess rain water thus maintained optimum moisture availability to the plants (Thakur et al 2011). Broad bed sand furrow method recorded significantly higher root weight compared to flat bed method during both the years. The root weight under broad bed sand furrow was 10.4 g and was 15.5 per cent higher over flat bed method. The increased root weight was due to decrease in the evaporation rate and availability of more soil water in profile for a longer period which facilitated better root growth. Increased soil moisture tension in flat bed method, exerts a physiological effect on the roots elongation, turgidity consequently the number of root hairs decrease with increasing tension.

Integrated nutrient management practices also significantly influenced the root weight of *Bt* cotton. Significantly higher root weight (11.6 g) was recorded with application of (S_5) 100% RDF + 25% RDN through pressmud treatment (Fig. 1). Pressmud is rich in beneficial microorganisms such as which aid in mineralization of plant nutrients in the soil and make them available to the plant roots. These microbes produce enzymes, auxins and other growth regulators, amino acids and many other organic acids which help in the proliferation of the root hairs and lateral roots of the tap root/fibrous root system. Next to this, application of 100% RDF + 25% RDN through FYM produced higher root dry weight (11.3 g). This may be ascribed to the improvement in the soil physico-chemical and biological properties due to the incorporation of organics along with 50 per cent recommended dose of fertilizers which might have hastened the nutrient availability as well as better soil conditions for root penetration. These results are in close agreement with the findings reported by Allam et al (2022). It was followed by application of 125% RDF (11.0 g), (S_1) Farmers practice (10.2 g) and (S_2) 100% RDF (9.4 g), respectively. This might be due to the higher and continuous nutrient availability from combined source up to the maturity that would have increased the overall growth of the plant including root.

Interaction between soil moisture conservation practices and integrated nutrient management practices were found to be significant during both the years of experimentation and in pooled results. Treatment combination involving poly mulch on broad bed and application of RDF along with 25% RDN through pressmud (M_4S_5) recorded significantly highest mean root weight (13.3 g). This treatment was on par with (M_4S_4) poly mulch on broad bed and application of RDF along with 25% RDN through FYM (12.9) followed by (M_4S_3) 125 % RDF. Thus, indicating that poly mulch on broad bed was comparatively more effective when RDF was applied either with pressmud or FYM.

Root volume: The root volume of *Bt* cotton was significantly affected by moisture conservation treatments. Poly mulch on broad bed method recorded significantly higher root volume during both the years as compared to rest of the moisture conservation treatments (Fig. 2). Pooled data analysis indicated that, the mean increase in root volume under poly mulch on broad bed (49.5) was 35.9, 21.6 and 13.2 per cent higher over flat bed, broad bed sand furrow and ridge sand furrow methods respectively. Maintaining high soil moisture content or higher water potential in Poly mulch on broad bed continuously favor better root development to a greater depth vertically and horizontal distance thereby coming in contact larger soil mass which enable the plants to absorb higher amount of moisture and nutrients. The enhancement in root length, secondary roots and root weight has been reflected in enhanced root volume. Halemani (2010) reported that mulching reduced the moisture loss by evaporation and there by conserved more amount of moisture in surface layer, reflecting in higher root growth. The ridge and furrow system followed M_5 and recorded significantly higher root volume as compared to broad bed sand furrow and flat bed methods during both the years. The mean increase in root volume under ridge sand furrow (43.7) was 20.0 and 7.3 per cent over flat bed and broad bed sand furrow methods. Broad bed sand furrow method recorded significantly higher root volume compared to flatbed method during both the years. The mean increase in root volume under broad bed sand furrow was 11.8 per cent higher over flatbed method. Integrated nutrient management practices also significantly influenced the root volume of *Bt* cotton. Significantly higher root volume (45.6) was recorded in (S_5)100% RDF + 25% RDN through pressmud treatment (Fig. 2). S_5 treatment was followed by (S_4) 100% RDF + 25% RDN through FYM (44.5). Significantly higher root volume may be attributed to FYM, which might have acted as a source of additional nutrients and moisture supply. Organics are known to have a favourable effect on soil structure, tilth and thus, facilitate quick and greater availability of plant nutrients and thus provide a better environment for root growth and proliferation (Ambika et al 2017a). This could be ascribed to higher and continuous nutrient availability from combined source up to the maturity. Similar findings were documented by Singh et al (2020). 100% RDF + FYM (S_4) was followed by 125% RDF (43.1), (S_1) farmers practice (41.0) and (S_2) 100% RDF (38.6).Interaction between treatment combination involving poly mulch on broad bed and application of RDF along with pressmud (M_4S_5) recorded significantly higher root volume (53.0). This treatment was found on par with (M_4S_4) poly mulch on broad bed and application of RDF along with FYM (44.5). M_4S_5 and M_4S_4 treatments were in turn on par with poly mulch on broad bed and application of 125% RDF (M_4S_3) indicating that poly mulch on broad bed was comparatively more effective when RDF applied along with either pressmud or FYM or 125% RDF alone.

NPK Uptake

Nitrogen (N) uptake (kg ha^{-1}): Application of poly mulch on broad bed method (M_4) recorded significantly higher N uptake at flowering and at harvest during both the years compared to rest of the moisture conservation treatments (Fig. 3). The poly mulch on broad bed recorded higher N uptake (89.9 sand 141.8 kg ha^{-1}) over flat bed, broad bed sand furrow and ridge sand furrow methods. Higher uptake of nutrients in mulched treatment might be due to the enhanced soil moisture availability that resulted in more solubilization of nutrients that lead to adequate availability and uptake by plants. These results are in agreement with the findings of Alzamel et al (2022). The ridge and furrow treatment (84.5 sand 128.4 kg ha^{-1}) followed S_5 and was on par with broad bed sand furrow (80.9 sand 118.4 kg ha^{-1}). The N uptake recorded with broad bed sand furrow method was comparable with flatbed method (76.8 sand108.1 kg ha^{-1}). The increased N uptake might be due to the improved soil moisture, which in turn lead to the enhanced uptake of nutrients. Broad bed and furrow system also has the advantage of draining excess water around the plant thus facilitating adequate aeration. Raised bed system improved the uptake of moisture and nutrients resulting in better plant growth with production of

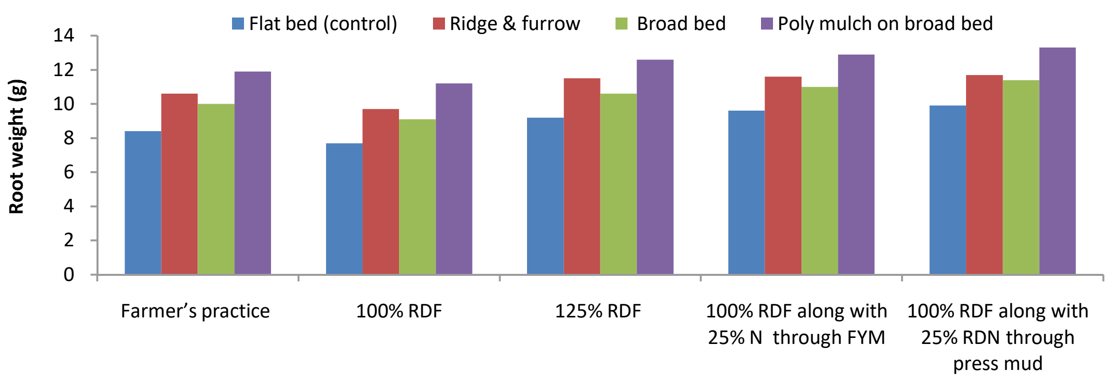

Fig. 1. Effect of moisture conservation practices and INM on root weight (g) of Bt cotton at 90 DAS

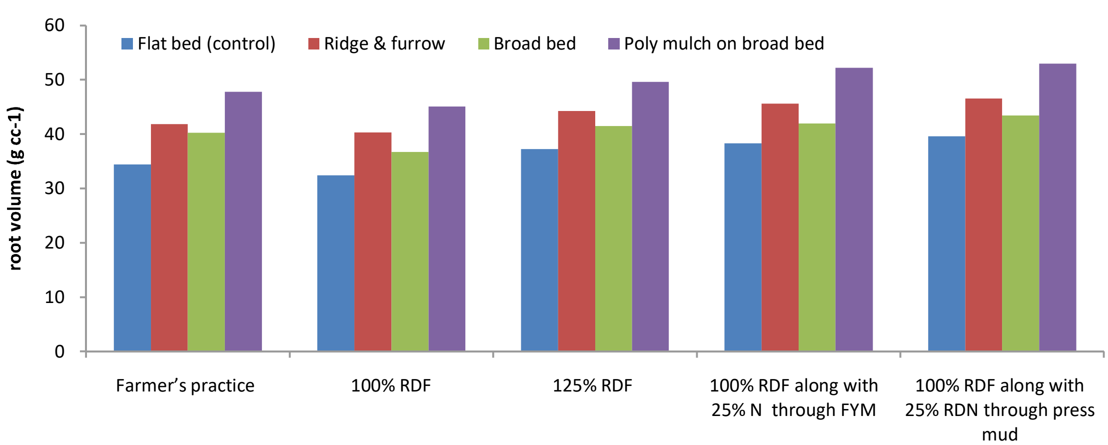

Fig. 2. Effect of moisture conservation practices and INM on root volume (g cc^{-1}) of *Bt* cotton at 90 DAS

higher dry matter plant^{-1} there by leads to higher uptake of nutrients.

Integrated nutrient management practices also significantly influenced the N uptake at flowering and at harvest (Fig. 3). Nitrogen uptake is the resultant of nutrient concentration and drymatter accumulation. Higher N uptake (85.6 sand 133.9 kg ha^{-1}) was recorded with 100% RDF + 25% RDN through pressmud equivalent to 25 % RDN (S_5). Rao et al (2005) have reported higher uptake of plant nutrients with the application of organic manures. Nutrient uptake invariably varies with nutrient content in the plant and dry biomass production as nutrient uptake is the product of drymatter and nutrient content. It could be observed from the data that except with 100% RDF, the nutrient removal by all the integrated nutrient management treatments was on par and supply of additional nutrients through organic fertilizers helped in uptake of more nutrients. Increased nitrogen uptake might be due to the direct addition of the N through pressmud and FYM and greater multiplication of soil microbes, which could convert organically bound N to inorganic form. Further, increased nitrogen uptake was also due to efficient root system with improved cell permeability coupled with better absorption due to better availability of nutrients in the soil solution (Sumathi and Rao., 2007). The interaction between soil moisture conservation practices and integrated nutrient management practices were significant on nitrogen uptake at flowering and at harvest. Treatment combination (M_4S_5) consisting of poly mulch on broad bed and application of RDF along with pressmud equivalent to 25% RDN recorded significantly highest N uptake at flowering (92.4 kg ha^{-1}) and at harvest (154.1 kg ha^{-1}). However, it was found on par with (M_4S_4) poly mulch on broad bed and application of 100% RDF along with FYM equivalent to 25 % RDN (92.0 kg ha^{-1}). M_4S_5 and M_4S_4 treatments were in turn on par with poly mulch on broad bed and (M_4S_3) application of 125% RDF indicating that poly mulch on broad bed was comparatively more effective when, RDF was applied either with pressmud or FYM equivalent to 25% RDN or 125% RDF alone. This might be due to the extended retention and availability of moisture coupled with higher drymatter production and nutrient content that resulted in higher N uptake as compared to corresponding lower level of fertilizer or inorganics alone.

Phosphorus (P) uptake (kg ha^{-1}): There was significant effect of moisture conservation treatments on P uptake at flowering and at harvest. Poly mulch on broad bed method (M_4) recorded significantly higher P uptake during both the years (Fig. 4). P uptake under poly mulch on broad bed (17.1 sand 28.4 kg ha^{-1}) was significantly higher over flat bed and broad bed sand furrow but it was comparable with ridge sand

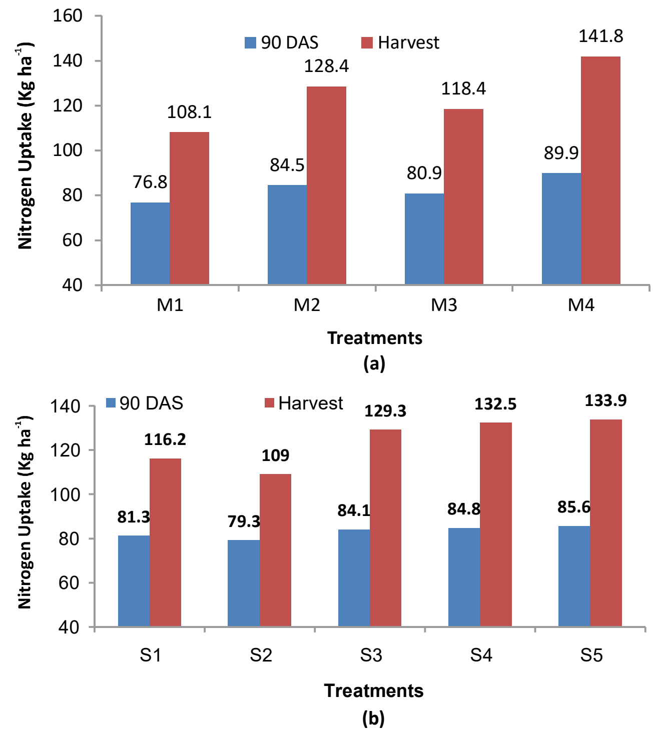

Fig. 3. Effect of (a) moisture conservation practices and (b) INM practices on Nitrogen (N) uptake (kg ha^{-1}) by *Bt* cotton at flowering and at harvest

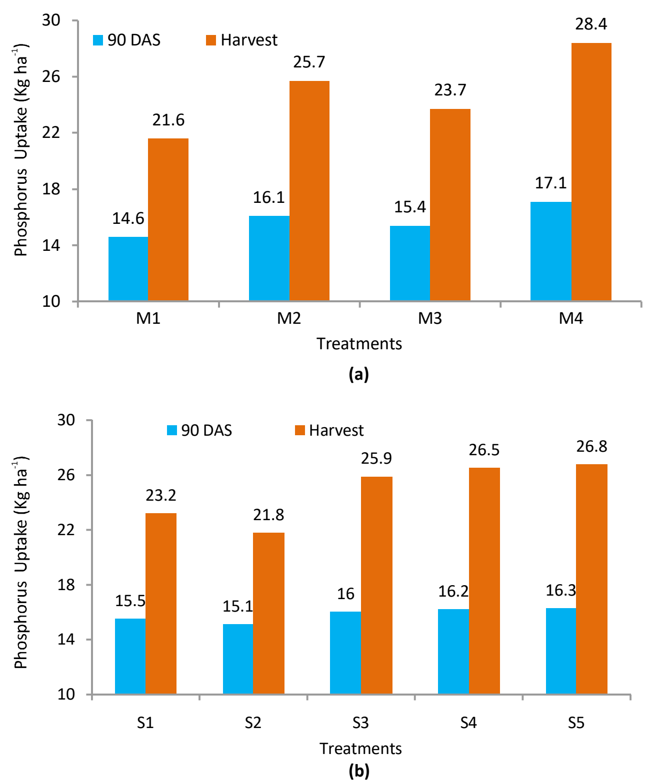

Fig. 4. Effect of (a) moisture conservation practices and (b) INM practices on phosphorus (P) uptake (kg ha^{-1}) by *Bt* cotton at flowering and at harvest

furrow method. Regulated temperature and faster mineralization under polyethylene mulching caused increased P uptake over other land configurations. The favorable hydro-thermal regime of soil and lower crop-weed competition under poly mulch has increased the P uptake. Hugar et al (2010) also reported that uptake of nutrients like N, P and K by the crop was better due to poly ethylene mulching and most effective when mulched with thicker PE film.

Integrated nutrient management practices also significantly influenced the P uptake at flowering of *Bt* cotton (Fig. 4). Application of 100% RDF + Pressmud equivalent to 25 % RDN (S_5) had recorded higher phosphorous uptake (16.3 sand 26.8 kg ha^{-1}) over (S_2) application of 100 % RDF but was on par with (S_4) 100% RDF + FYM equivalent to 25 % RDN and 125% RDF followed by (S_1) Farmers practice . Increased P uptake in S_5 treatment was due to the direct addition of the P through pressmud and greater multiplication of soil microbes, which could convert organically bound P to inorganic form. The organic materials form a cover on sesquioxides and thus, reduce the phosphate fixing capacity of the soil. These results are in accordance with Raut et al (2008).

The interaction effect on phosphorous uptake at flowering and harvest was significant due to moisture conservation and integrated nutrient management practices. The treatment combination (M_4S_5 and M_4S_4) involving poly mulch on broad bed and application of 100% RDF along with either pressmud or FYM equivalent to 25% RDN had recorded higher mean P uptake at flowering (17.6 and 17.6 kg ha^{-1}) and at harvest (30.8 and 30.4 kg ha^{-1}), respectively. Thus, indicating that poly mulch on broad bed was comparatively more effective when RDF applied either with pressmud or FYM or application of 125% RDF alone. Higher drymatter production coupled with higher phosphorous content that reflected in higher P uptake at both stages of *Bt* cotton.

Potassium (K) uptake (kg ha^{-1}): Potassium (K) uptake among moisture conservation treatments exerted significant influence at flowering and at harvest (Fig. 5). Poly mulch on broad bed method recorded significantly higher K uptake (64.8 and 152.8 kgha^{-1}) during both the years compared to flat bed (55.3 and 116.4 kg ha^{-1}) and broad bed and furrow methods (58.3 and 127.6 kgha^{-1}) but it was comparable with ridge and furrow at flowering and significantly superior at harvest (64.8 and 138.2 kg ha^{-1}). This significant response could be due to the significant dry matter production among the treatments at different crop growth stages. The favorable hydro-thermal regime of soil, higher temperature, faster mineralization and lower crop weed competition under poly mulch had increased the K uptake by plants. At flowering, ridge and furrow, which in turn was comparable with broad bed and furrow method during both the years of experimentation, whereas, ridge and furrow treatment was significantly superior over BBF at harvest. Broad bed sand furrow and flat bed methods were on par with each other. This was due to the optimum availability of moisture that led to higher uptake of K for proper growth and development of plants, resulted in higher K uptake as compared to flat bed method. The major portion of potassium moves to the roots by diffusion process though water films around the soil particles. In flat bed, under moisture stress condition the films become thinner and path length of ion movement increases. Hence, movement of potassium to the roots reduced.

Application of inorganics along with organics and graded level of fertilizers had exerted significant influence on potassium uptake at flowering (Fig. 5). Application of (S_5) 100% RDF + Pressmud equivalent to 25 % RDN treatment had recorded higher potassium uptake (61.6 and 144.0 kg ha^{-1}) over remaining integrated nutrient management practices. S_5 treatment was on par with (S_4) 100% RDF + FYM equivalent to 25 % RDN and application of (S_3) 125% and. (S_2) 100% RDF was followed by (S_1) Farmers practice. S_1 was in turn comparable with (S_2) 100 % RDF (57.1 and 117.3 kg ha^{-1}). Higher K uptake could be due to the significant

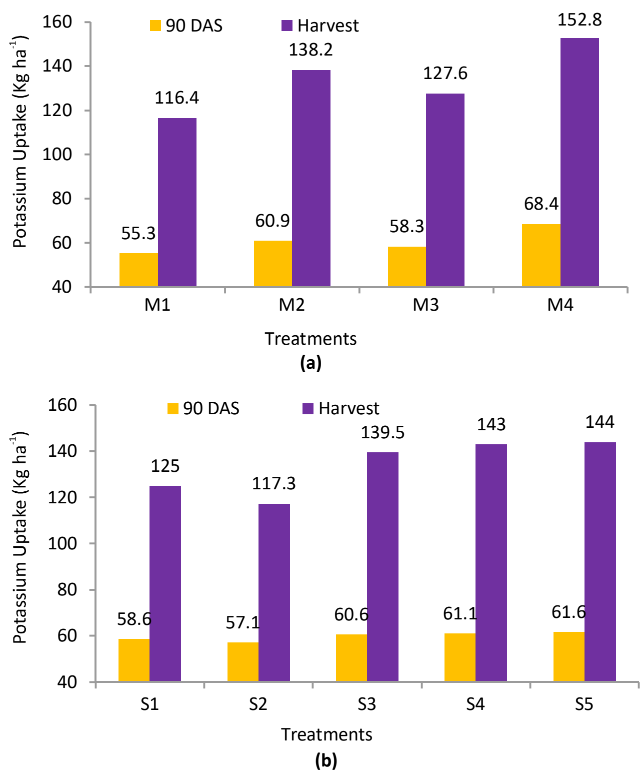

Fig. 5. Effect of (a)moisture conservation practices and (b) INM practices on potassium (K) uptake (kg ha^{-1}) by *Bt* cotton at flowering and at harvest

drymatter production among the treatments at flowering. Higher uptake of potassium under S_5 treatment was due to addition of potassium to available pool of the soil besides the reduction in potassium fixation and release of potassium.

Interaction between soil moisture conservation practices and integrated nutrient management practices were significant on K uptake during both the years of experimentation and in pooled results. Treatment combination M_4S_5 involving poly mulch on broad bed and application of RDF along with pressmud equivalent to 25% RDN recorded significantly highest mean K uptake at flowering and at harvest (66.6 and 166.0 kg ha^{-1}). This treatment was found on par with M_4S_4 poly mulch on broad bed and application of RDF along with FYM equivalent to 25% RDN and M_4S_3 application of 125% RDF. Thus, indicating that poly mulch on broad bed was more effective when RDF was applied either with pressmud or FYM or application of 125% RDF alone.

Physical, Physico-Chemical and Chemical Properties of Soil

Soil OC (%): The initial soil organic carbon content was 0.41 (%). There were no significant differences among the moisture conservation practices and nutrient management practices and due to their interaction during both the years of experimentation (Table 3). However, slight increase in OC was observed in 100% RDF + pressmud (0.42 %) or FYM equivalent to 25 % RDN (0.42 %) applied plots. The soil OC values varied between 0.40 to 0.42 % with relatively higher values in treatments consisting of organics (FYM and pressmud) over inorganics alone. Kumar et al (2017) also indicated the efficiency of pressmud based organics improve physical and chemical properties of soil.

Available N (kg ha^{-1}): The initial soil available nitrogen was 182 kg ha^{-1}. The post-harvest nitrogen status of the soil varied non significantly due to moisture conservation practices and significantly due to INM practices during both the years of study. However, their interaction effect was found to be non-significant (Table 3). The land configuration treatments had no significant effect on available nitrogen content of soil after harvest of the crop. However, the available nitrogen content varies between 179.7 and 186.1 kg ha^{-1} among different moisture conservation treatments. Integrated nutrient management practices also significantly influenced the available N after harvest of *Bt* cotton. Application of 125% RDF (194.3 kg ha^{-1}) recorded significantly higher available nitrogen as compared to rest of the treatments. This was on par with farmers practice and remaining treatments and significantly superior over 100 % RDF (160.7 kg ha^{-1}). The increase in available nitrogen under 125% RDF and also with organic manures was due to the direct supply of higher nitrogen as well as enhanced microbial activity which improved the nitrogen transformations like ammonification and nitrification. In farmers practice, application of higher dose of nitrogen (184 kg ha^{-1} and 3.75 t FYM ha^{-1}) lead to increase in available nitrogen. The results are in agreement with the findings of Satyanarayana Rao and Janawade (2009). Interaction between soil moisture conservation practices and integrated nutrient management practices were non-significant during with respect to pooled results.

Available P (kg ha^{-1}): The available phosphorous content of soil also increased with maturity of the crop. There was a buildup of available P_2O_5 over the initial value of 46.8 kg P_2O_5 ha^{-1}. The available P was significantly affected by moisture conservation practices and integrated nutrient management practices during both the years of experimentation. The interaction effect was also significant (Table 4). The initial soil test value indicated that it had soil available phosphorous of 46.8 kg ha^{-1}. The data indicated significant effect of moisture conservation treatments on soil available P. Poly mulch on broad bed method recorded significantly higher P availability (57.4 kg ha^{-1}) during both the years compared to all other

Table 3. Effect of moisture conservation practices and INM on OC (%)and available nitrogen(kg ha^{-1}) (Pooled data)

Treatments	OC (%)	Available nitrogen (kg ha^{-1})
Main treatments		
M_1 – Flat bed (Control)	0.41	179.7
M_2 – Ridge sand furrow	0.41	184.0
M_3 – Broad bed and furrow	0.41	182.1
M_4 – Poly mulch on broad bed	0.41	186.1
CD at 5%	NS	NS
Sub treatments		
S_1	0.41	193.0
S_2	0.41	160.7
S_3	0.40	194.3
S_4	0.42	182.2
S_5	0.43	184.7
CD at 5%	NS	14.6
CV	7.3	8.8
Interaction		
M XS		
CD at 5%	NS	NS
S X M		
CD at 5%	NS	NS

S_1 : Farmers practice, S_2 : 100% RDF, S_3 : 125% RDF, S_4 : 100% RDF + FYM equivalent to 25% RDN , S_5: 100% RDF + Pressmud equivalent to 25% RDN moisture conservation. The less loss of phosphorus has aided in buildup of soil phosphorus up to harvest as compared initial status in poly mulch treatment. Poly mulch treatment was followed by ridge and furrow (54.0 kg ha^{-1}), which was on par with BBF and also recorded significantly higher available P as compared to flat bed method (51.2 kg ha^{-1}). Broad bed sand furrow method was in turn on par with flatbed method. Raised bed land configuration improves physico-chemical environment of soil through facilitating adequate air and water movement and ultimately improves nutrient availability. Similar results have also been earlier reported by Raising and Karthik (2022). Integrated nutrient management practices also significantly influenced the soil available P of *Bt* cotton. Significantly higher soil P (57.2 kg ha^{-1}) was in farmers practice (S_1) treatment. This was due to application of higher dose of P (101 kg P_2O_5) at later stages *i.e.* 20-25 DAS and 40-45 DAS of crop growth, which was not taken by the crop in farmers practice. This was on par with (S_3) application of 125% RDF (57.0 kg ha^{-1}). Increase in soil available phosphorus was due to direct addition of P from high dose of inorganic fertilizer. Next best treatment was (S_5) 100% RDF + Pressmud equivalent to 25 % RDN which was on par with 100% RDF + FYM equivalent to 25 % RDN (S_4) followed by (S_2) application of 100% RDF. Kalaivanan and Omar Hattab, (2008) reported improvement in soil physico-chemical properties with application of pressmud to soil. Interaction between soil moisture conservation practices and integrated nutrient management practices were found to be significant during both the years of experimentation and in pooled results. Treatment combination involving poly mulch on broad bed and farmers' practice (M_4S_1) recorded significantly highest mean soil available P (60.5 kg ha^{-1}). This treatment was on par with (M_4S_3) combination of poly mulch on broad bed and application of 125 % RDF. All *in-situ* moisture conservation treatments along with farmers practice recorded higher soil available P. Significantly lower soil available P was observed in the treatments applied with pressmud and FYM which was due to increased uptake of nutrients by the crop. These results revealed that the *Bt* cotton crop removed substantial amount of phosphorous towards growth and development to meet its requirement.

Available K (kg ha^{-1}): Available K content of the soil increased in all the treatments compared to the initial status during both the years of experimentation except (S_2) application of 100% RDF during 2015-16. Available K was not influenced by moisture conservation practices and significantly influenced by integrated nutrient management practices during both the years (Table 4). The initial soil test value indicated that it had soil available potassium of 432.0 kg ha^{-1}. The land configuration treatments had no significant effect on available potassium content of soil after harvest of the crop. Integrated nutrient management practices significantly influenced the available K of *Bt* cotton (Table 4). During both the years of experimentation, among different INM practices, (S_1) farmers practice (447.0 kg ha^{-1}), (S_3) application of 125% RDF (442.1 kg ha^{-1}) and (S_5) 100% RDF + Pressmud equivalent to 25 % RDN (438.6 kg ha^{-1}) were on par with each other and recorded significantly higher post-

Table 4. Effect of land configurations and nutrient management practices on available phosphorus(kg ha^{-1}) and available potassium (kg ha^{-1}) in the soil

Treatments	S_1	S_2	S_3	S_4	S_5	Mean
Available P (kg ha^{-1}) pooled						
M_1 - Flatbed (control)	54.5	45.3	58.2	47.7	50.2	51.2
M_2- Ridge sand furrow	57.8	51.0	55.4	52.3	53.5	54.0
M_3- BBF	56.0	49.1	55..3	50.6	51.0	52.4
M_4- Poly mulch on BBF	60.5	57.0	59.3	55.0	55.2	57.4
Mean	57.2	50.6	57.0	51.4	52.5	53.8
C.D at 5%		2.0	1.2	2.5	2.7	
Available K (kg ha^{-1})						
M_1 - Flatbed (control)	442.3	420.4	437.1	429.0	433.5	432.5
M_2- Ridge sand furrow	448.1	430.5	443.5	440.0	441.2	440.7
M_3- BBF	444.4	426.1	441.0	432.7	435.5	435.8
M_4- Poly mulch on BBF	453.0	435.2	446.6	442.4	444.2	444.3
Mean	447.0	428.0	442.1	435.9	438.6	438.3
C.D at 5%		NS	10.5	12.2	15.5	
CV		7.4				

harvest potassium values over application of (S_2) 100 % RDF (428 kg ha^{-1}). This could be due to more intense weathering, release of K from pressmud, application of K fertilizers and upward translocation of potassium from lower depth along with capillary raise of groundwater. (S_5) Application of 100% RDF + Pressmud equivalent to 25 % RDN was on par with (S_4) application of 100% RDF + FYM equivalent to 25% RDN (435.9 kg ha^{-1}). These findings are in agreement with those of Yadav et al (2019) and Umesh et al (2018). Interaction between soil moisture conservation practices and integrated nutrient management practices were found to be significant during both the years of experimentation and in pooled results. Treatment combination involving poly mulch on broad bed and farmers' practice (M_4S_1) recorded significantly highest mean available K (453 kg ha^{-1}).This treatment was on par with combination of ridge sand furrow configuration with farmers' practice of nutrient application (M_2S_1). All *in-situ* moisture conservation treatments along with farmers practice recorded higher soil available K followed by all *in-situ* moisture conservation treatments along with 125 % RDF. With increased application of K level, the soil available K also increased. Significantly lower available potassium was observed in the treatments applied with pressmud or FYM which was due to increased uptake of nutrients by the crop.

CONCLUSION

BBF laid with poly mulch in addition to application of 100% RDF + 25% RDN through organics (pressmud or FYM) was comparable to BBF laid with poly mulch and application of 125% RDF through inorganics in terms of yield attributes (bolls per plant and boll weight) and seed cotton yield, root weight and volume, NPK uptake by plant, and available organic carbon (%) and available soil NPK status, among the land configuration treatments. Application of 100% RDF + 25 % RDN through Pressmud has recorded highest yield and yield attributes, root weight and volume, NPK uptake and available NPK status in the soil which was at par with 100% RDF + FYM equivalent to 25 % RDN and 125% RDF alone among the nutrient management practices. Based on the results, poly mulch on broad bed in combination with either pressmud or FYM or application of 125% RDF alone can be well recommended to farmers of Telangana. Therefore, it can be concluded that poly mulch on broad bed was comparatively more effective when RDF applied along with either pressmud or FYM or application of 125% RDF alone can be well recommended to farmers of Telangana.

REFERENCES

Allam M, Radicetti E, Quintarelli V, Petroselli V, Marinari S and Mancinelli R 2022. Influence of organic and mineral fertilizers on soil organic carbon and crop productivity under different tillage systems: A Meta-Analysis. *Agriculture* **12**(4): 464.

Alzamel NM, Taha EM, Bakr AA and Loutfy N 2022. Effect of organic and inorganic fertilizers on soil properties, growth yield, and physiochemical properties of sunflower seeds and oils. *Sustainability* **14**(19): 12928.

Ambika V, Yadahalli GS, Chittapur BM, Kulkarni S, Yadahalli VG and Malakannavar S 2017a. Influence of land configuration and nutrient levels on soil moisture and yield of bt cotton under rainfed situation. *International Journal of Pure and Applied Bioscience* **5**(6): 396-401.

Ambika V, Yadahalli GS, Chittapur BM, Shamrao Kulkarni, Yadahalli VG and Malakannavar S 2017. Influence of land configurations and nutrient levels on growth, yield and economics of Bt cotton. *International Journal of Current Microbiology and Applied Science* **6**(12): 3095-3102.

Cotton association of India. 2018-19. http://www.caionline.in /articles/cotton-advisory-board-cab-pegs-2018-19-cotton-crop-at-36-1-mln-bales.

DCD (Directorate of Cotton Development) 2017. *Status Paper of Indian Cotton* In: Directorate of Cotton Development, Government of India.

Dhaker DL, Kumar B, Karthik R and Raj M 2022. Effect of sequential application of herbicides on weed management, productivity and nutrient uptake of direct seeded rice. *Indian Journal of Ecology* **49**(6): 2149-53.

Fuchs M and Hadas A 2011. Mulch resistance to water vapour transport. *Agricultural Water Management* **98**: 990-998.

Ghulam S, Khan MJ, Usman K and Ullah S 2012. Effect of different rates of pressmud on plant growth and yield of lentil in calcareous soil. *Sarhad Journal of Agriculture* **28**(2): 249-252.

Gokhale DN, Chavan AS and Raskar SK 2012. Influence of in situ soil moisture conservation and INM techniques on yield and economics of rainfed *Bt* cotton. *Journal of Cotton Research and Development* **26**(2): 190-193.

Halemani HL 2010. Influence of polyethylene mulching on soil moisture, nutrient uptake and seed cotton yield. *Indian Journal of Agricultural Research* **44**(3): 189-194.

Hugar AY, Halemani YR, Aladakatti RA, Nandagavi and Hallikeri SS 2010. Studies on the effect of polyethylene mulching on rainfed cotton genotypes: II. Influence on status of soil moisture, microbial population in soil and uptake of nutrients. *Karnataka Journal of Agriculture Science* **22**(2): 284-288.

Jagadish Kumar and Yadav MP 2010. Effect of foliar application of nutrients on seed cotton yield and economics in Hirsutum cotton. *Journal of Cotton Research and Development* **24**(1): 71-72.

Kalaichelvi K 2009. Bt cotton response to plant geometry and fertilizer levels. *Journal of Cotton Research and Development* **23**(1): 96-99.

Kalaivanam D and Omar Hattab K 2008. Influence of Enriched Pressmud Compost on soil chemical Properties and Yield of Rice. *Research Journal of Microbiology* **3**: 254-261.

Karthik R, Dhaker D and Raising LP 2022. Performance of Cereals under Need based Nitrogen Management Strategies: A Review. *Agricultural Reviews* **43**(3): 320-326.

Kumar S, Meena RS, Jinger D, Jatav HS and Banjara T 2017. Use of pressmud compost for improving crop productivity and soil health. *International Journal of Chemical Studies* **5**(2): 384-389.

Kumari ChP, Suneetha Devi KB, BhanuRekha K, Sridevi S and Narender Reddy S 2018. Influence of moisture conservation practices and integrated nutrient management practices on yield, quality and economics of Bt cotton. *Journal of Pharmacognosy and Phytochemistry* **7**(6): 2672-2676.

Mehta AK, Thakral SK and Saharan HS 2009. Effect of organic and inorganic sources of nutrition on yield and fibre quality of cotton (*Gossypium hirsutum*). *Journal of Cotton Research and Development* **23**(2): 255-257.

Mudhalvan S, Rajeswari S, Mahalingam L, Jeyakumar P, Muthuswami M and Premalatha N 2021. Causation studies for

Kapas yield, yield components and lint quality traits in Mexican cotton (*Gossypium hirsutum* L.). *Environment Conservation Journal* **22**(3): 357-363.

Nalayani P, Anandham R, Sankarnarayanan K and Rajendran TP 2009. Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum*) and maize (*Zea mays*) cropping system. *Indian Journal of Agronomy* **54**(4): 409-414.

Narkhede WN, Nayak S, Sutar VK and Jaware BH 2015. Effect of land configuration and nutrient management on yield, quality and moisture use efficiency of *Bt* cotton. *Agriculture for Sustainable Development* **3**(1): 60-63.

Patel P, Patel JC, Mehta RS and Vyas KG 2015. Response of Bt and non-Bt cotton (*Gossypium hirsutum* L.) hybrids to varying sowing time. *Journal of Cotton Research* **29**(2): 273-276.

Prasad MVR and Sudhakara Babu SN 1997. *Technology for dryland agriculture.* Monograph in agriculture sand Environment Series. ICAR, New Delhi, India. pp:39.

Raising LP and Karthik R 2022. Effect of integrated phosphorus management on productivity, nutrient uptake, nutrient content and soil properties of summer sesame (*Sesamum indicum* L.). *Journal of Oilseeds Research* **39**(2): 108-112

Rao S and Janawade AD 2005. Studies on integrated nutrient management in irrigated hybrid cotton. *Karnataka Journal of Agricultural Sciences* **20**(1): 212-215.

Raut RS and Mehetre SS 2008. Integrated nutrient management in *hirsutum* cotton cv.NHH-44 under summer irrigated conditions. *Journal of Cotton Research and Development* **22**(1): 48-49.

Satyanarayana Rao and Janawade AD 2009. Influence of integrated nutrient management practices on physic-chemical properties of cotton growing soils. *Journal of Cotton Research and Development* **23**(1): 60-63.

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Singh H, Dhillon BS and Yadav S 2020. Influence of Farmyard Manure and Nitrogen on Performance of Bt Cotton (*Gossypium hirsutum* L.). *International Journal of Current Microbiology and Applied Sciences* **9**(10): 704-711.

Solunke PS and Sangita U andFatak 2011. Influence of organic and inorganic sources of nutrients on production of desi cotton under different plant protection measures. *Journal of Cotton Research and Development* **25**(1): 42-45.

Sumati V and Koteswar Rao DS 2007. Effect of organic and inorganic sources of nitrogen with different irrigation schedules on growth and yield of sunflower. *Indian Journal of Agronomy* **52**(1): 77-79.

Thakur NS, Kushwaha BB and Sinha NK 2011. Productivity and water use in *kharif* sorghum (Sorghum biclolor) under different land configurations and mulching. *Indian Journal of Agronomy* **56**(1): 47-51.

Umesh UN, Prasad RK and Kumar V 2018. Integrated effect of organic and inorganic fertilizers on yield, quality parameter and nutrient availability of sugarcane in calcareous soil. *Journal of Pharmacognosy and Phytochemistry* **7**(1S): 556-560.

Vieira JLV, Nardi KT, Silva GRA, Moreira LA, Zavaschi E, Moura TA and Otto R 2018. Nutrient uptake by high-yielding cotton crop in Brazil. *Rev Bras CiencSolo* **42**: e0170033.

Xie Z, Wang Y, Jiang W and Wei X 2006. Evaporation and evapotranspiration in a watermelon field mulched with gravel of different sizes in northwest China. *Agricultural Water Management* **81**: 173-184.

Yadav SK, Benbi DK and Prasad R 2019. Effect of continuous application of organic and inorganic sources of nutrients on chemical properties of soil. *International Journal of Current Microbiology and Applied Sciences* **8**(4): 2455-2463.