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Various tillage systems and sowing methods affect growth and yield related characters of cotton

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ABSTRACT

Seedbed preparation and sowing methods play a significant role in obtaining good crop yields. To explore the agronomic productivity and economic efficacy of different tillage and sowing methods in cotton, a two year field study was conducted during 2010 and 2011. The experiment comprised of two tillage systems viz; conventional tillage (one time disc harrow + two cultivations + planking) and deep tillage (chiselling twice + one cultivation + planking) along with three sowing methods viz; flat sowing, ridge sowing and bed sowing. Split plot design was used with three replications. Deep tillage amplified seed cotton yields by 18.7% and 11.14% during 2010 and 2011, respectively. Bed sowing exhibited higher yield contributing traits such as a number of opened bolls per plant and boll weight as compared to the ridge and flat sowing. Deep tillage with bed sowing gave maximum net returns of USD 1407.88 with BCR of 1.81 during the year 2010, while during 2011 it was USD 783.50 with BCR 1.45. The bulk density of the soil was found lower in the upper layer of soil surface as compared to the lower surface under deep tillage systems as compared to conventional tillage systems. It was concluded that deep tillage produced number of plants which contributed towards highest seed cotton yield. Moreover, deep tillage was more costly except in bed sowing of the cotton crop. The interactive effect of tillage systems and sowing methods were found non-significant during both years of study.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) plays a vital role in Pakistan's economy (Ibrahim *et al.*, 2007; Ahmad *et al.*, 2015). It is the lifeline of the textile industry in the country. According to an assessment, an increase of one million bales in cotton production will result in an increase of half a percent in the gross domestic product (GDP). Realizing the immense importance of cotton crop in building the economy of Pakistan, extensive studies are on-going to improve the yield potential of the crop under the local environmental conditions (Ahmad *et al.*, 2014).

Cotton is a natural fibre crop and due to its unique quality, it is called silver-fibre (Arshad and Anwar, 2007). Cotton is used for several products ranging from clothes to home furnishings and medical products. So, cotton is continuously in demand due to its diversified usages and is connected to the powers and weaknesses of the overall economy of Pakistan. Worldwide, Pakistan is the fifth largest producer, fourth largest consumer of cotton and the largest exporter of cotton yarn (1.3 million out of 5 million) (Govt. of Pakistan, 2012-13). In Pakistan, the area under cotton crop is 3 million ha and its share in GDP is

1.5% with a contribution in value added to the agriculture of 7.0% (Govt. of Pakistan, 2012-13). Currently, the cotton crop is facing a number of restraints, resulting in low yield per ha. Some of the constraints include costly agricultural inputs (seed, fertilizers, pesticides etc), pest attack, lack of pest and disease resistant varieties, good quality seed, scarcity of irrigation water, improper cultivation method and unavailability of advanced technologies. Tillage operations, irrigation and sowing methods are also important factors that greatly affect crop productivity. The good management of these variables may increase the production of cotton. Effective tillage systems build an ideal seedbed condition for seed germination, proper plant stand and unhindered root growth (Atkinson *et al.*, 2007; Krause *et al.*, 2009). The purpose of tillage operations, that an expensive part in the cotton production, is to incorporate residues, enhance water infiltration, and prepare an appropriate seedbed and to enhance the soil root penetration. Previously, different tillage and planting methods have been practised in various regions of Pakistan depending on climate, topography and soil properties to explore their efficiency. Ridge and bed planting are used in different crops under different climatic conditions because both provide labour saving, increase in soil fertility, improved water management, enhanced water use efficiency, erosion control, enrich rooting depth and better pest management (Lal, 1990). Boydas and Turgut (2007) reported that tillage was an act to improve soil conditions for proper crop emergence and yield. Soil moisture level, soil compaction and bulk density are important factors affecting the growth and yield of the crop (Memon *et al.*, 2007). Maximum tillage operations to craft seedbed cause soil compaction and imbalance between air and water components of soil and also increase the soil strength to restrict root growth; although a little compaction is also required for better contact of seed with soil particles (Memon *et al.*, 2007). Well-developed root systems with the ability to explore greater soil volume have been recognized as an important adaptation of plants to ensure sufficient water and nutrient uptake (Horst *et al.*, 2001). Soil and water resources, as well as sustainability of agricultural production, are degraded due to conventional tillage systems (Gupta *et al.*, 2003). Repeated cultivation at the same depth or annual ploughing creates subsoil hardpan (Kukal and Aggarwal, 2003) whereas according to Haakansson (2005), reduction in soil compaction (e.g., bulk density) is must in

order to obtain good soil tilth. For any tillage practice, various tillage tools and operational variables are used as they affect soil physical properties such as water contents, penetration resistance, bulk density and emergence rate index. Deep tillage and irrigation provide accumulative soil water for a crop and it augments soil water by disturbing the soil profile to enhance the size and number of macrospores in the soil, making deeper root penetration (Hoeft *et al.*, 2000). Alamouti and Navabzadeh (2007) found pronounced effects of deep tillage on soil bulk density, infiltration rate, and crop yields as compared to semi-deep and shallow tillage systems with increasing ploughing depth. Blaise and Ravindran (2003) reported enhanced yields of cotton by ridge tillage (RT) compared with conventional tillage (CT) planting system whereas Pringle and Martin (2003) found that under watered conditions. Deep tillage did not increase cotton yield and was uneconomical.

Planting methods are an important factor which affects crop growth and development and finally the crop yield. Proper planting techniques ensure healthy growth. Recently, various planting methods such as flat sowing, ridge planting and bed planting for the cotton crop are being practised in Pakistan. The ridge tillage (RT) planting system gave higher lint yield and more earliness than conventional planting system (CT) and cotton grown on beds produced more seed cotton yield as compared to the ridge and flat sowing (Ali *et al.*, 2010). Whereas cotton crop grown using bed and furrow planting method with plastic sheet/film mulching technique produced sustainable cotton production and better water economy (Iftikhar *et al.*, 2010). Along with the adoption of a wide range of conventional agriculture practices all over the world, permanently raised bed planting is being more important for various row-spaced crops. Benefits associated with permanent raised beds included better irrigation management which saved 25-30 % of irrigation water with increased water productivity and improved nutrient availability (Sayre and Hobbs, 2004; Hassan *et al.*, 2005). Additionally, Nasrullah *et al.* (2011) also found bed and furrow method in cotton cultivation more efficient than flat sowing regarding water use efficiency. Keeping in view, the above discussion about the prevailing contradictions regarding the impact of deep tillage and sowing methods on the cotton yield, this study was planned with the objectives to assess most suitable and economical tillage system and planting methods and its impact on the ultimate yield of cotton.

MATERIALS AND METHODS

Experimental details: The study was conducted in two consecutive years 2010 and 2011. The geographical location of the site was latitude 31.25° N and longitude 73.09° E. The soil type was sandy loam. The experiment was laid out in a randomized complete block design (RCBD) with the split-plot arrangement. Treatments were comprised of two factors, A) tillage systems (main plot); a) conventional tillage (one disc harrow + two cultivations + planking) and b) deep tillage (chiselling twice + one cultivation + planking) and B) sowing methods (subplot); a) flat sowing, b) ridge sowing and c) bed sowing).

Crop husbandry: The soil was prepared using one time disc harrow along with two cultivations followed by planking in conventional tillage, while, in deep tillage, the soil was prepared with two time chiselling and one time cultivation followed by planking. Ridges were made using ridge and beds with bed-shaper. Sowing was done on 28th May 2010 and 26th May, 2011 during both years. Fertilizer at the rate of 150 kg ha⁻¹ of N, 120 kg ha⁻¹ P₂O₅ and 120 kg ha⁻¹ K₂O was applied. Half of N and the full amount of P and K were applied at the time of sowing. The remaining half of Nitrogen was applied with first irrigation. Plant protection measures were adopted to keep crop free of insects and diseases. First picking was carried out on 50 % boll opening. The last picking was done on 17th of November during 2010, while on 20th November during 2011. Data were collected by following the standard procedures.

Meteorological Data: Meteorological data such as daily maximum and minimum air temperature (°C), rainfall (mm) and sunshine hours were collected from the nearby observatory of the Department of Crop Physiology, University of Agriculture, Faisalabad, Pakistan and presented in Figure 1.

Measurement of soil bulk density: Bulk density was determined by taking four undisturbed soil cores from each plot; two at 0–15 cm depth and the other two at 15–30 cm depth. Cores were taken by hammering into the ground with the stainless steel cutting edge cylinders 5 cm high and 6 cm in diameter. The volume of the cylinder was calculated by using the equation: $V = \pi r^2 h$, where V is the volume (cm³), r is the inner radius (cm) and h is the height (cm) of the cylinder. The cores were stored and transported in hermetic cans. This ensured that the samples would remain at their field water content. The samples were dried at 105 °C for 48 h in an oven and were

weighed. Soil bulk density was calculated by using the formula (Blake and Hartage, 1986):

Soil bulk density (g cm⁻³) = oven-dry mass of soil / Total volume of soil including pore spaces.

Economic analysis

Net return: The Net return was determined by subtracting the total cost of production from the gross income of each treatment (CIMMYT, 1988).

Net income = Gross income – Cost of production

Benefit-cost ratio: Benefit-cost ratio (BCR) was calculated by dividing gross income by the total cost of production.

BCR = Gross income / Total cost

Preparation of graphs and figures was done by using the Microsoft Excel, Sigma plot and for statistical analysis of the data Computer programme MSTAT-C (Russel and Eisensmith, 1983) was used. To test the overall significance of the data Fisher's analysis of variance technique was applied and least significant difference (LSD) test at P < 0.05 was used to compare the differences among the treatment means (Steel *et al.*, 1997).

RESULTS

Number of plants m⁻²: Different tillage systems and sowing methods had a significant effect on the number of plants m⁻² of cotton. A higher number of plants m⁻² (5.39) was recorded by deep tillage as compared to conventional tillage (5.28 plants m⁻²) during 2010 (Table 1). A similar trend was found in 2011 (Table 1) where deep tillage produced 5.62 plants m⁻², while, conventional tillage gave 5.42 number of plants m⁻². Among sowing methods, during 2010, bed sown cotton produced a significantly higher number of plants m⁻² (5.41), while, the minimum number of plants (5.26) were obtained in the flat sown cotton crop during 2010. During the next year, a similar trend was observed but ridge planting was found at par with flat sown cotton producing 5.44 plants m⁻².

Sympodial branches per plant: Greater number of sympodial branches per plant (12.92) was recorded in deep tillage as compared to conventional tillage (11.8) during 2010 and similar trend was observed during 2011, where significantly higher sympodial branches (16.57) were recorded in deep tillage systems, while, 15.62 sympodial branches were recorded in conventional tillage system, whereas, all sowing methods showed significant variation in producing sympodial branches per plant.

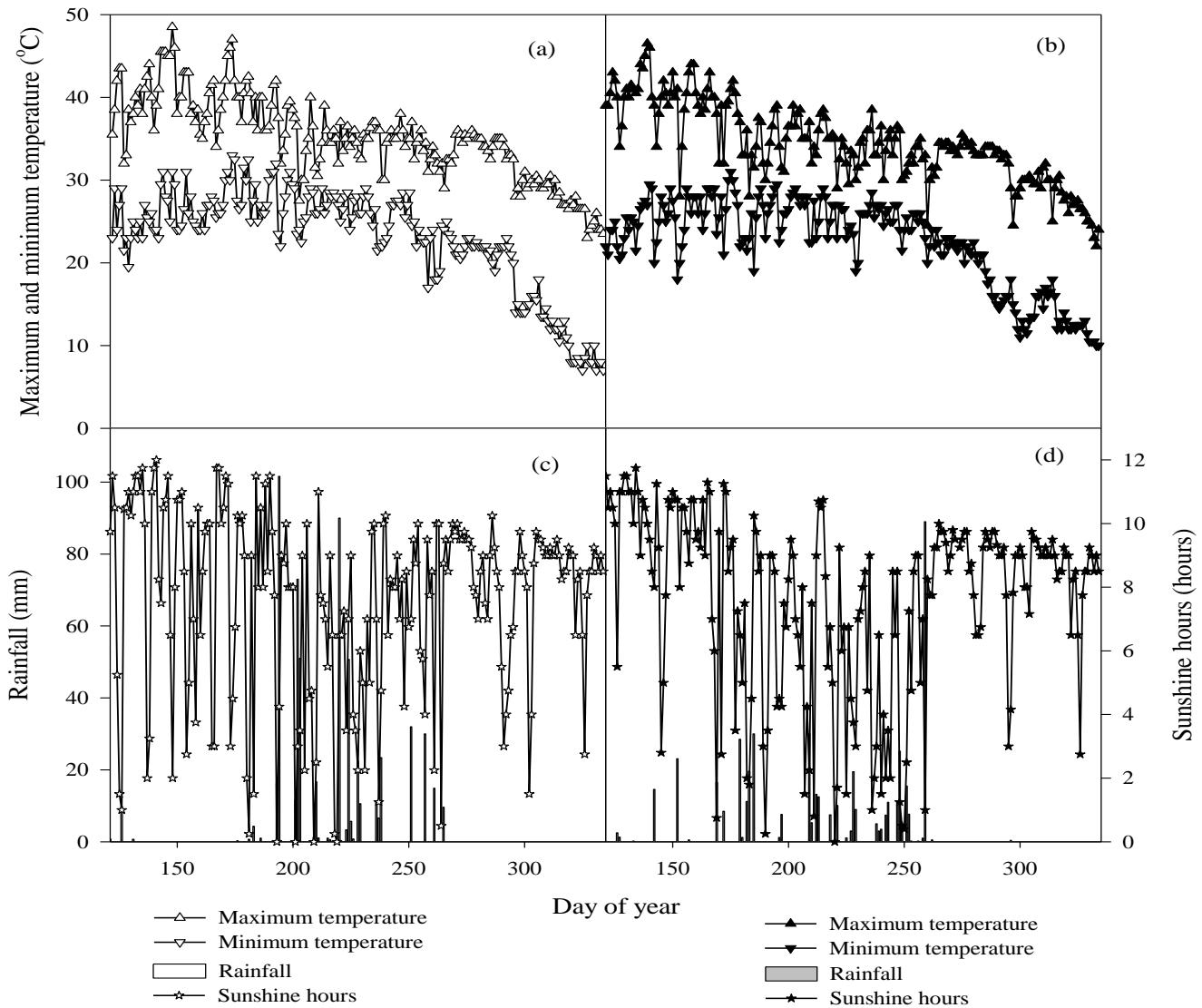


Figure 1. Daily maximum and minimum temperatures (a, b), rainfall and sunshine hours (c, d) during 2010 (un-filled symbols) and 2011 (filled symbols) at Faisalabad, Pakistan.

Bed planting proved best regarding the growth and development of sympodial branches and produced 13.50 and 17.50 branches which were statistically at par with ridge planting 12.67 and 16.30 branches, respectively, **Number of opened bolls per plant:** Data depicted in Table 1 revealed significant effect of tillage systems and different sowing methods on a number of opened bolls per plant during both the years of experiment, while, the interactive effect showed non-significant variation. Significantly more number of opened bolls per plant (26.69) was recorded in deep tillage compared with conventional tillage which produced 25.01 bolls during 2010. A similar trend was observed during 2011 by deep

while, flat sowing lagged behind regarding production of sympodial branches and produced 10.90 and 14.49 sympodial branches respectively, during both growing seasons (Table 1). tillage producing 33.01 opened bolls per plant which was higher than the conventional tillage system (30.12). While, in the case of sowing methods, bed sowing produced number of open bolls per plant (27.80) which was statistically similar to ridge sown cotton. Significantly the lowest number of opened bolls (23.46) was recorded in cotton planted under flat sowing method during 2010. During next year the trend was changed where bed sown cotton produced a significantly maximum number of

opened bolls per plant (33.36) and a considerable decrease was observed by ridge planting, while, flat planting gave the least number of opened bolls per plant (29.65).

Boll weight (g): Boll weight is the major yield contributing attribute. Significantly higher boll weight (3.0 g) was recorded in deep tillage system as compared to conventional tillage system during 2010 (Table 1). A similar trend was recorded during 2011, where higher boll weight (3.26 g) was recorded in deep tillage, while, lower (2.73 g) was observed in conventional tillage. Different sowing methods significantly affected the boll weight producing highest boll weight (2.95 g) in cotton grown on beds which were at par with ridge planted cotton having boll weight of 2.81 g. Minimum boll weight (2.50 g) was recorded in flat sown cotton. The almost similar trend was observed during following the growing season. Cotton grown on beds produced highest boll weight (3.23 g) and it was at par with ridge planting (3.11 g). Minimum boll weight (2.65 g) was found in flat planted cotton (Table 1).

100-seed weight: 100-seed weight or seed index is a key factor which contributes integral share in ginning outturn (GOT) in cotton, which is affected by temperature, moisture availability, crop growth, boll maturity and environmental circumstances. Deep tillage produced a higher 100-seed weight of 7.3 g as against 7.21 g for conventional tillage during 2010 (Table 1). During year next greater 100-seed weight of 7.34 g was recorded in deep tillage followed by conventional tillage yielded 7.17 g 100-seed weight. Moreover, different sowing methods affected 100-seed weight significantly (Table 1). During 2010, significantly greater 100-seed weight (7.53 g) was recorded in cotton grown on beds and followed by 7.28 g obtained in cotton planted on ridges, while, the lowest 100-seed weight (6.96 g) was observed in flat sown cotton. Furthermore, bed and ridge sowing produced statistically same 100-seed weight (7.44 g and 7.34 g, respectively) and both were at par with 6.99 g for cotton grown in flat planting method during 2011.

Seed Cotton Yield (kg ha⁻¹): Statistical analysis of data revealed a significant influence of different tillage systems as well as sowing methods on seed cotton yield in both growing seasons. However, the interactive effect of these two factors was found non-significant (Table 1). Cotton grown under deep tillage produced maximum seed cotton yield (2343 kg ha⁻¹) which was higher than the conventional tillage system (1973 kg ha⁻¹) during 2010. The almost similar trend was recorded during

2011, where, the highest seed cotton yield (2498 kg ha⁻¹) was obtained in deep tillage compared with conventional tillage (2247 kg ha⁻¹). Additionally, cotton grown on beds gave positively high yield (2384 kg ha⁻¹) which was at par with yield obtained under ridge sowing, whereas, flat planting produced minimum seed cotton yield (1898 kg ha⁻¹) during the year 2010, while, in subsequent year both bed and ridge sowing gave statistically same yield (2525 and 2425 kg ha⁻¹, respectively) and flat sown cotton produced significantly least yield of 2168 kg ha⁻¹.

Ginning out turn (%): Ginning out turn was calculated to determine the percentage of lint in seed cotton yield. Deep tillage showed GOT (36.78 %), while, (36.44 %) was observed in conventional tillage system during 2010, while, during subsequent year GOT of 36.39 % was recorded in deep tillage whereas conventional tillage resulted in 35.93 % GOT. Sowing methods had a non-significant effect on GOT during the first year of study while in next year sowing methods showed significant variation in GOT. Bed sowing produced maximum GOT (36.88 %) closely followed by ridge and flat sown cotton where 36.78 %, 36.17 % GOT was recorded, respectively but did not differ statistically. During 2011, bed sowing produced significantly higher GOT (37.25 %) followed by (36.04 %) GOT recorded in cotton grown on ridges and minimum (35.20 %) GOT was recorded in flat sown cotton.

Bulk Density: During 2010 (Figure 2) deep tillage exhibited 11.60 % lower soil bulk density than conventional tillage systems in the upper layer of the soil depth (0-15 cm) while it was 6.57 % lower in the lower layer of soil depth (15-30 cm). During next year a similar trend was recorded. In the second year, deep tillage decreased soil bulk density up to 8.74% in the upper layer of soil depth and 6.9% in the lower layer of soil depth compared with conventional tillage system (Figure 2). Sowing methods had no effect on soil bulk density. Statistically, similar bulk density was recorded at various sowing methods during 2010 in the upper layer of the soil surface (0-15cm) whereas in lower soil surface under deep tillage sowing methods showed a significant effect. Bed sowing produced higher bulk density followed by ridge planting. Minimum soil bulk density was recorded in flat sowing method. During 2011 the trend was changed. Sowing methods had no effect on soil bulk density at both the soil surface depths. Although there was a slight variation in soil bulk density values obtained in various sowing methods it could not reach the level of significance.

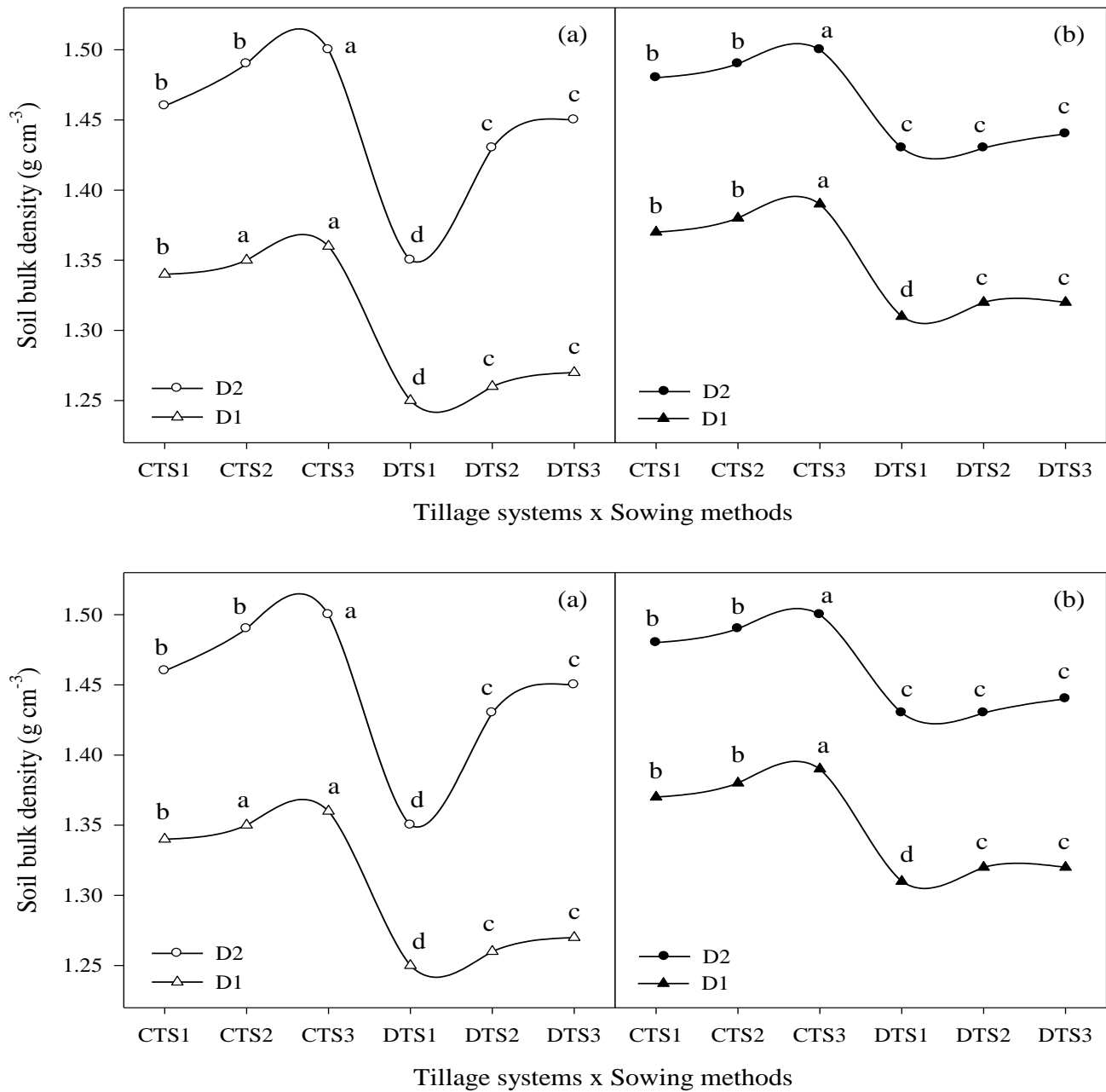


Figure 2. Effect of tillage systems and sowing methods on the bulk density of soil during 2010 (a) and 2011 (b). Note: CTS1 (Conventional tillage flat sowing) CTS2 (Conventional Tillage Ridge sowing) CTS3 (Conventional Tillage Bed Sowing) DTS1 (Deep tillage flat sowing) DTS2 (Deep Tillage Ridge sowing) DTS3 (Deep Tillage Bed Sowing) D1 (Depth 0-15 cm) D2 (Depth 15-30 cm).

Root Length: Roots are the basic part of the plant, which plays a prime role in plant growth and yield. Roots are affected by soil physical, chemical and biological properties. The cotton crop is sensitive to root growth. It is a tap-rooted crop. Loose soil allows deeper elongation of roots as compared with compacted soils. Data depicted

in Table 1 revealed that tillage systems significantly affected root length during both growing seasons. Sowing methods also affected root length significantly during the course of the experiment. The interactive effect of tillage systems and sowing methods on the root length showed non-significant effect.

Table 1. Effect of tillage systems and sowing methods on yield and yield related attributes of cotton.

Treatments	plants m ⁻²		Sympodial branches/plant		opened bolls/plant		100-seed weight (g)		Ginning out turn (%)		Boll weight (g)		Seed Cotton Yield (kg ha ⁻¹)		Root Length	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Flat sowing	5.3c	5.4b	10.9b	14.5b	23.5b	29.7c	7.0c	7.0b	36.2	35.2c	2.5b	2.7b	1898b	2168.2b	31.0b	36.2b
Ridge sowing	5.3b	5.5b	12.7a	16.3a	26.3a	31.7b	7.3b	7.3a	36.8	36.0b	2.8ab	3.1a	2193ab	2425.3a	33.3b	37.7ab
Bed sowing	5.4a	5.6 a	13.5a	17.5a	27.8a	33.4a	7.5a	7.4a	36.9	37.3a	2.9 a	3.2a	2384a	2525.3a	36.9a	40.9a
LSD (p≤0.05)	0.02	0.03	1.04	1.62	1.66	1.24	0.10	0.31	ns	0.67	0.35	0.28	301.7	239.49	3.34	3.10
Tillage	5.3b	5.4b	11.8b	15.6b	25.0b	30.1b	7.2	7.2	36.4	35.9	2.5b	2.7b	1973b	2247b	30.0b	35.3b
Deep Tillage	5.4a	5.6a	12.9a	16.6a	26.7a	33.0a	7.3	7.3	36.8	36.4	3.0a	3.3a	2343a	2498a	37.5a	41.2a
LSD(p≤0.05)	0.01	0.03	0.88	0.57	1.65	2.41	ns	ns	ns	ns	0.30	0.31	288.32	156.73	7.32	4.27

Table 2. Effect of different tillage system and sowing methods on total cost, net return and benefit-cost ratio of cotton during 2010 and 2011.

Treatment	Yield (kg ha ⁻¹)		Value (US Dollar ha ⁻¹)		Cotton Sticks Value (US Dollar)		Gross Income (US Dollar ha ⁻¹)		Total Cost (US Dollar ha ⁻¹)		Net Return (US Dollar ha ⁻¹)		Benefit Cost Ratio		
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	
Conventional tillage	Flat sowing	21.02	23.38	2101.92	1870.08	115.82	114.17	2217.74	1984.24	1566.48	1572.83	651.26	411.43	1.42	1.26
	Ridge Sowing	22.72	26.10	2272.06	2087.73	115.82	114.17	2387.89	2201.90	1598.16	1613.83	789.73	588.07	1.49	1.36
	Bed Sowing	24.84	27.51	2484.48	2201.07	115.82	114.17	2600.30	2315.24	1608.78	1620.92	991.52	694.34	1.62	1.43
Deep tillage	Flat sowing	22.95	26.13	2295.00	2090.56	115.82	114.17	2410.82	2204.73	1686.17	1695.07	724.65	509.67	1.43	1.30
	Ridge Sowing	28.10	29.28	2809.71	2342.55	115.82	114.17	2925.53	2456.72	1735.07	1738.21	1190.46	718.51	1.69	1.41
	Bed Sowing	30.39	30.15	3038.57	2411.87	115.82	114.17	3154.39	2526.04	1746.51	1742.55	1407.88	783.50	1.81	1.45

(During 2010): Seed cotton price = 46.33 US Dollar per 40 kg

Cotton sticks value = 115.82 US Dollar per hectare

(During 2011): Seed cotton price = 36.53 US Dollar 40 kg

Cotton sticks value = 114.17 US Dollar per hectare

During 2010 deep tillage produced longer roots of 37.48 cm followed by conventional tillage producing root length of 29.98 cm. A similar trend was observed during 2011 where deep tillage gave enhanced root length up to 41.24 cm as against the minimum (35.33 cm) recorded in

conventional tillage system. Higher root depth of cotton obtained in deep tillage may be attributed to deep manipulation of the soil, increased soil porosity and lower soil bulk density (Fig. 2). With regard to sowing methods, during 2010 cotton grown on beds produced maximum root length of

36.94 cm and it was followed by ridge planting. Root length of 31.01 cm was observed in the flat sown crop which was at par with ridge planting of cotton. During next year, the trend was changed.

Bed and ridge planting gave 40.86 cm and 37.72 cm, respectively root length and were statistically similar while minimum root length was found in flat sown cotton.

Economic analysis

Net Return: During the year 2010, the overall environment was unfavourable due to heavy monsoon rainfall that ultimately affected crop yield. While during subsequent year (2011) the environment was favourable. Timely rainfall at critical stages, optimum temperature and more sunny days well supported the growth of cotton that's why the overall yield in 2011 was more than 2010. During 2010 deep tillage with bed sowing gave a maximum net return of Rs. 121556 while during 2011 it was Rs. 68627 in the same treatments. Although yield during 2011 was more as compared to 2010 yet decrease in net returns during 2011 was due to lower cotton market prices than 2010. No doubt, the yields of bed sown plots prepared after deep ploughing was statistically higher due to which net return was more than rest of the treatments. During 2010, overall cotton production was lower due to more rainfall and flood occurrence in the country; due to lesser availability of cotton than demand its market value was raised (Table 2). During the next growing season, the environment was favourable, overall cotton production was higher than the previous year. Due to the increase in price during 2010 area under cotton crop during 2011 was increased, furthermore, environmental conditions favoured crop productivity which resulted in higher seed cotton production. As a result, cotton became surplus in the market which reduced its market price. So, for obtaining more net returns it was recommended that cotton should be sown on beds after deep ploughing as it gave a maximum net return of Rs. 121556 and Rs. 68627 during 2010 and 2011, respectively (Tables 2). In this way, farmers can get more returns of their cost applied on cotton production. These results were well supported by others Sharma *et al.* (2011), they reported higher net returns in deep tillage than conventional tillage.

Benefit cost ratio: During 2010 under deep tillage system bed sowing gave maximum BCR of 1.81 which was 21.61 % higher than all other treatments followed by ridge planting (1.69 BCR) (Table 2). Flat sown cotton produced minimum BCR of 1.43. A similar trend was calculated in the conventional tillage system. Under this system, bed sowing gave maximum BCR of 1.62 and it was followed by ridge sowing method producing BCR of 1.49. Minimum BCR (1.42) was found in flat sown cotton under

Ridge and flat planting produced statistically similar root length lower than bed planting.

conventional tillage system. A similar trend was found during 2011 (Table 2). Benefit cost ratio was low due to price differences. Highest BCR (1.45) was obtained in deep ploughed bed sown cotton which was 12.97 % greater than rest of the plots. It was followed by ridge planted cotton giving 1.41 BCR. Minimum benefit cost ratio of 1.30 was observed in flat sown cotton under deep tillage system. Under conventional tillage system highest BCR (1.43) was obtained in bed sown cotton. It was followed by ridge planting producing 1.36 BCR and minimum BCR of 1.26 in flat sown cotton. Bed planting under deep tillage system gave maximum benefit cost ratio compared with rest of the treatments during both years (Table 2). These results were quite comparable with the results of Sharma *et al.* (2011) they reported the highest benefit cost ratio in deep tillage than conventional tillage.

DISCUSSION

In flat sown cotton especially during 2010, the poor germination was observed due to rainfall showers and crust formation, here, maximum germination in bed sown cotton was recorded and it was followed by ridge planting and ultimately a number of plants was maintained. The number of plants in deep tillage might be due to better soil tilth, improved seedbed preparation facilitating more moisture availability which resulted in better germination. These results are supported by the findings of Ozpinar and Cay (2006) who reported that high seed zone moisture enhanced the seedling emergence by decreasing the mean weight diameter by ploughing and disking. They found 3% more plants in deep ploughing as compared to conventional tillage. Moreover, it was found that a higher number of plants in bed sowing compared with other sowing methods (ridge sowing, drilling and broadcasting) (Ali *et al.*, 2010).

The increase in sympodial branches might be attributed to the early emergence and proper stand establishment in deep tillage and cotton grown on beds as compared to conventional tillage and flat sowing where germination of cotton occurred 3-4 days later than other planting methods. Furthermore, a higher number of sympodial branches in deep tillage was due to deep root proliferation resulting in better plant growth producing more sympodial branches per plant. These findings are

contradictory to the results reported by a group of scientists Dangolani and Narob (2013) who conducted a similar trial to evaluate different cotton varieties under different tillage systems and stated that a number of sympodial branches were not significantly affected by different tillage systems. Prevailing environmental conditions during the experiment influenced its growth as more rainfall was recorded during 2010 than 2011, which affected the cotton growth badly. Furthermore, it was documented by Ali *et al.* (2010) that different sowing methods significantly affected sympodial branches in cotton.

Deep ploughing provided maximum water utilization at fruit-bearing stage, better maturity and ultimately more opening of bolls. In bed sowing more light penetration occurred and an ample amount of light enhanced boll opening. During the first growing season, more rainfall and low temperature affected crop growth badly resulting in stunted growth, while, during net growing season conditions were favourable which provided better vegetative and reproductive growth. Climatic conditions promoted earliness of cotton, development and maturity of cotton bolls resulting in greater boll opening. These results are supported by the outcomes of a group of scientists Goyne and McIntyre (2001).

Higher boll weight in deep tillage might be ascribed to the more vigorous growth of plants. In the case of deep tillage, more crop growth rate was observed. Further, deep ploughing helped in the deep proliferation of roots which provided an opportunity for ample absorption of nutrients from the soil and greater moisture availability which ultimately, resulted in substantial higher boll weight. Well-spaced plants had better light penetration in bed sown cotton throughout the growing period produced higher boll weight compared with flat planted cotton. It was also found higher boll weight in flat sowing with earthing up as compared to flat sowing McAlavy (2004). The increase in 100-seed weight under deep tillage was might be due to deep roots proliferation which facilitated better nutrients absorption, higher water availability, mature boll formation resulting in vigorous seeds. These results were found contradictory to the findings of scientists (Ali *et al.*, 2010 b) who found a non-significant effect on the 100-seed weight of cotton planted under different sowing methods. As far as, increase in yield on bed and ridge planted cotton was concerned it was due to early germination and emergence of the crop compared to flat sowing and deeper root proliferation

explored more roots surface area for absorption of water and nutrients. These results are correlated with the findings of scientists Chauhan (2007) who found 35 % higher seed cotton yield in the cotton-wheat rotation in bed sowing method and it was superior to flat sowing. Deep ploughing induced loosening of soil and breaking of hardpan might facilitate deep root proliferation of cotton and enabled the crop to absorb more nutrients and water and ultimately resulted in improved yield. Schwab and co-workers also found more seed cotton yield under deep tillage. They also narrated that increase in yield was due to the removal of compacted layers with deep tillage facilitating the roots to explore up to a larger soil volume to obtain nutrients and moisture.

An experiment was conducted at three different locations to investigate the effect of different planting methods on cotton performance and water saving percentage and reported that the planting methods had non-significant effect on GOT at all three locations (Ali *et al.*, 2010) but found contradictory to others who investigated impact of tillage systems and nitrogen levels on cotton and pointed out that tillage systems positively affected GOT due to favourable environmental conditions. The decrease in soil bulk density may be ascribed to that deep ploughing caused more soil inversion and mixing which enhanced soil porosity, decreased soil penetration resistance, and exposed most of soil surface area to sunlight resulting in decreased ability to hold water contents over time. These results were supported by similar findings of Osunbitan *et al.* (2005) and Pedrotti *et al.* (2005) who found that deep tillage management influenced soil quality and plant growth as a result of altering physical, chemical and biological properties. In contrast, highest soil bulk density in conventional tillage was due to more soil compaction, less soil disturbance and reduced evaporation. Alvarez and Steinbach (2009) also reported higher soil bulk density in zero tillage or less disturbed soil. These results were contradictory with the findings of Altuntas and Dede (2009). They reported that soil bulk density was affected by different sowing methods. According to their finding, soil bulk density was lower in ridge planting and it was due to the reason of lower soil penetration for ridges. The soil was less compacted and allowed roots to penetrate deeper. These results were confirmed by the findings of Beulter and Centurion, (2004) who recorded longer roots in deep tillage. Lopez-Bellido *et al.* (2007) also reported the shorter root length of crops in zero tillage than conventional tillage due to surface soil

compaction.

CONCLUSION

It is concluded deep tillage produced a number of plants as compared to conventional tillage during both growing seasons. Economic analysis showed all other planting methods except bed planting become costly when deep tillage was employed. Therefore, bed sowing gave more yield and net return than any other sowing method, affirming that bed sowing is most economical with less negative effects on cotton growth and yield traits.

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