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Growth and Yield of Cotton (*Gossypium hirsutum* L.) as Influenced by Deep Ploughing Interval on Sandy Loam Soil

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ABSTRACT

Deep ploughing interval studies for cotton crop were conducted at Adaptive Research Farm, Karor district Layyah over an eight years period on sandy loam soil. The treatments comprised of deep ploughing with one year to five years interval and a shallow cultivation as check. The results revealed that heights of cotton plants decreased as the interval of deep ploughing increased. The harvestable bolls per plant ranged with different deep ploughing intervals from a maximum of 50% to a minimum of 28% over and above the shallow cultivation. Cotton planted with deep ploughing of two years interval produced the highest seed cotton yield of 1719 kg ha^{-1} followed by deep ploughing every year (1669 kg ha^{-1}), while shallow cultivation gave the lowest seed cotton yield of 1307 kg ha^{-1}. The crop grown with deep ploughing of three and four years interval displayed significantly higher seed cotton yields of 1574 and 1557 kg ha^{-1}, respectively than that deep ploughed after five years interval (1521 kg ha^{-1}). Different deep ploughing intervals increased seed cotton yield from 16 to 33% over the shallow cultivation. On the basis of economic analysis, it was recommended for the farmers of Thal areas in the Punjab that cotton fields should be deep ploughed after four years interval at the time of land preparation with a maximum cost benefit ratio of 1:2.30.

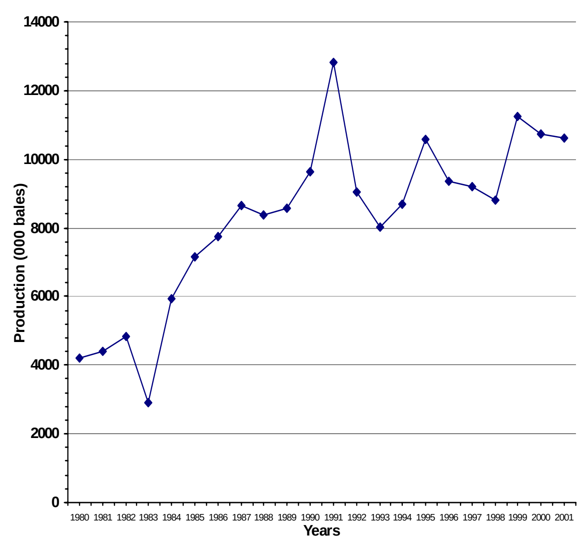
Key Words: *Gossypium hirsutum* L.; Deep Ploughing interval; Growth; Yield; Pakistan

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is the leading industrial crop of Pakistan which is grown on 3116 thousand hectares with annual production of 10613 thousand bales and accounts for 11.7% of value added in agriculture and about 2.9% of GDP (Anonymous, 2003). The crop supports over a large number of rural families and its sale makes a major contribution to the earnings of foreign currency. However, there are sharp fluctuations between years and cotton production in Pakistan during the last two decades (Fig. 1) which is mainly due to the variation in average seed cotton yield per unit area. The cotton farmers in the country usually plough their fields with tractor drawn spring tine cultivator which hardly tears soil upto 15 cm depth. They are accustomed to excessive ploughings with this implement at shallow depths. Cotton is intensively tilled crop both at the time of land preparation and during the growing season. Due to continuous cultivation of crops, a subsoil compacted layer is formed at certain depth constantly. In addition, accumulation of high exchangeable sodium and illuviation of clay to the subsoil horizon may also form a subsoil hard layer in different soils. These compacted layers in the subsoil horizon are referred to as tillage pans, plow pans, hard pans or plow soles. These layers lower the infiltration and percolation rates, nutrient movement and free air transport with in the soil profile which affects crop growth and yield.

Root growth is generally not as prolific in the compacted layer as in uncompacted soil (Parish, 1971).

Fig. 1. Annual cotton production of Pakistan, 1980-2001



Reduction of root growth in and below a tillage pan reduced the volume of soil available for the plant to exploit for water and nutrients there by limiting yield potential (Chancellor, 1977). Tillage pans reduce water infiltration and redistribution rates, thus limiting the benefit of irrigation (Reicosky *et al.* 1981). During periods of intensive rain fall or irrigation, water may perch on the tillage pan and place oxygen stress to plants. Crops grown on areas of fields with a tillage pan are more severely affected by droughty conditions than areas without a tillage pan. Drought stress to crops is aggravated by tillage pan because of restriction of upward water movement by capillary action from deeper soil horizons (Gill, 1971).

Alleviation of compacted soil used to grow cotton was investigated by Spurgeon *et al.* (1978) who found that yields and profits were significantly increased by subsoiling a silt loam soil to a depth of 16 to 20 inch. Whereas, Tompkins *et al*. (1979) concluded that subsoiling of a silt loam soil did not significantly affected cotton yields. Similarly other studies (Tupper & Spurgeon, 1981) conducted on silt loam soil showed no significant seed cotton yield increases from subsoiling suggesting that this particular soil had no compacted horizons or that the subsoiling was ineffective. The trials conducted at Adaptive Research Farms and farmers fields in Vehari, Rahim Yar Khan and Sargodha registered 14.57, 5.98 and 10.17% increase of seed cotton yield with chiseling twice over shallow cultivation respectively (Anonymous, 1984). Soil compaction can affect the growth and possibly reduce yield of cotton (Hadas *et al.,* 1985). Tupper and Musick (1985) while conducting deep tillage studies on fine sandy loam and silt loam soils observed increased lint yield above the no deep tillage treatment. They concluded that double subsoiling produced the greatest net return on silt loam soils. Cotton plants grown in non subsoiled areas were shorter than those grown in subsoiled areas (McConnel *et al.,* 1989). Likewise, the harvestable bolls were less in cotton grown in non subsoiled areas than in cotton grown where subsoiling was used to disrupt the pan, consequently subsoiling increased lint yield between 11.6 and 40.7% in two different silt loam soils. The application of deep tillage practices on fine textured soils did not provide any significant seed cotton yield advantage over the shallow cultivation (Ahmad & Haffar, 1993). They suggested that cotton farmers should be devoted to shallow tillage practices only, due to less expensive during land preparation. Basker *et al.* (1995) recommended that soils with subsoil hard pan should be ploughed with chisel plow once in a three years period. Reeves *et al.* (1995) concluded that subsoiling was necessary to maximize cotton yield on sandy loam soils. A substantial increase in seed cotton yield was recorded by Phipps *et al.* (2000) due to deep tillage during the first two years; whereas, a small increase was observed in the third year.

Apart from the few research studies above, little information is available on the effect of deep ploughing on seed cotton yield in Pakistan. Limited research has generally shown benefits of deep tillage practices over the shallow and conventional tillage. The present study was therefore initiated with the objective of determining benefits of deep ploughing with optimum interval in the cotton fields in Thal areas of Punjab.

MATERIALS AND METHODS

Deep ploughing interval studies for cotton crop were conducted at Adaptive Research Farm, Karor district Layyah and extended over eight seasons from 1994 to 2001. The experimental site was on a sandy loam field containing 18% clay, 31% silt and 51% fine sand. Six tillage treatments and three replicates with a total of 18 field plots measuring 15 x 25 m were adjusted in a randomized complete block design. Each plot received the same deep ploughing treatment throughout the study periods. Chisel plough of three tines to a depth of 30 cm at 60 cm apart was used criss-cross for deep ploughing with the following treatments:

T1 = Deep ploughing every year
T2 = Deep ploughing after every two years
T3 = Deep ploughing after every three years
T4 = Deep ploughing after every four years
T5 = Deep ploughing after every five years
T6 = No deep ploughing (shallow cultivation)

Every year deep ploughing was done at the time of land preparation for cotton sowing according to the schedule elaborated in Table I.

Table I. Schedule of deep ploughing interval

Tr.	1994	1995	1996	1997	1998	1999	2000	2001
T1	**	**	**	**	**	**	**	**
T2	**	-	**	-	**	-	**	-
T3	**	-	-	**	-	-	**	-
T4	**	-	-	-	**	-	-	-
T5	**	-	-	-	-	**	-	-
T6	-	-	-	-	-	-	-	-

** Cross chiseling in respective treatment and year
- Shallow cultivation in respective treatment and year

The cotton cultivar planted in the experiment was CIM-109. All other cultural practices such as planting during first week of May, fertilization, tillage operations, weed and insect control and irrigation were uniform for the entire field as recommended by the department for the area. Heights of cotton plants were measured for each treatment plot at randomly chosen locations near maturity. Number of bolls was counted at random locations in 10 different plants selected from the centre 10 rows of each treatment plot after the crop was fully matured. Only open, well fluffed bolls were included in the count there by providing a better estimation of yield potential than total bolls counts, which would have included immature and unharvestable bolls. Individual plot yield of seed cotton was hand picked and weighed in the field. The total seed cotton yield per hectare per season was then computed using the observed yield from individual plots. Yield data were then averaged and per cent increase was calculated over check. Statistical analysis was under taken on averaging plant height, bolls per plant and seed cotton yield per unit area obtained from each replication every year by using Fisher`s analysis of variance technique. Duncan`s new multiple range (DMR) test was employed at 5% level to test the significance of differences of means (Steel & Torrie, 1984).

Economic analysis was conducted to determine the optimum deep ploughing interval and the cost benefit ratio was reckoned on the basis of additional cost and income relative to shallow cultivation. The additional income of each treatment was derived by averaging eight years seed cotton yield and calculated on the basis of Rs.25/kg, the prevailing market rate during 2001, whereas, the additional cost of each deep ploughing treatment was computed on the basis of Rs. 680/ha/run.

Meteorological data for the experimental years were collected from the observatory installed at Government Seed Farm, Karor operated by the Agriculture Extension Department, Government of the Punjab (Fig. 2 & 3). The 1994-2001 kharif seasons were different in respect of rain fall. The years 1994-1998 were characterized by the plenty of rains throughout the season, whereas 1999-2001, the last three years of the study received low precipitation. The temperature exhibited about the same trend in different years but with variation in magnitude.

RESULTS AND DISCUSSION

Plant height. There were highly significant differences in plant height among the various deep ploughing interval treatments under study (Table II). Deep ploughing, regardless of the interval, increased plant height as compared with shallow cultivation. Average plant height decreased as the interval of deep ploughing increased. The maximum average plant height of 149.8 cm was recorded in the plots, deep ploughed every year as against the lowest of 122.4 cm in shallow cultivated plots. The plots deep ploughed after every four years produced taller plants (139.2 cm) than that deep ploughed after every five years (138.8 cm), however, the differences between the two treatments were found to be non-significant. These non-significant differences between the two intervals were probably attributed to almost uniform growth rate of the plants towards height in these treatments. An increase of 13 to 22% in plant heights were recorded in different deep ploughing intervals as compared with shallow cultivation treatment.

Changes in plant height as a result of deep ploughing were recorded during all the years of the study. Plant height remained relatively high in all the years due to deep ploughing. Significant differences in plant height as a result of deep ploughing interval became evident just after the next year of the study during 1995. The early years of the measurements of heights of cotton plants were not found to be significantly different in the plots, deep ploughed during 1994 and ploughed with shallow cultivator only in subsequent years according to their schedule of deep ploughing interval. The plant heights of every year deep ploughed treatment proved its superiority over the other treatments throughout the experimental years except 1994. This can be attributed from maximum root growth in deep ploughed plots every year which correlates with increased rooting at deeper depths below the hard pan for the treatment compared with other deep ploughing and shallow cultivation as previously reported (Parish, 1971). The plant heights of the shallow cultivation and the every fifth year

Fig. 2. Average maximum and minimum temperatures for the experimental years during the crop growth period

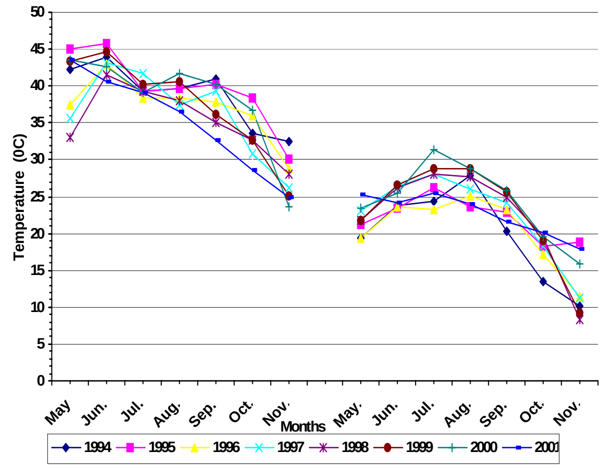
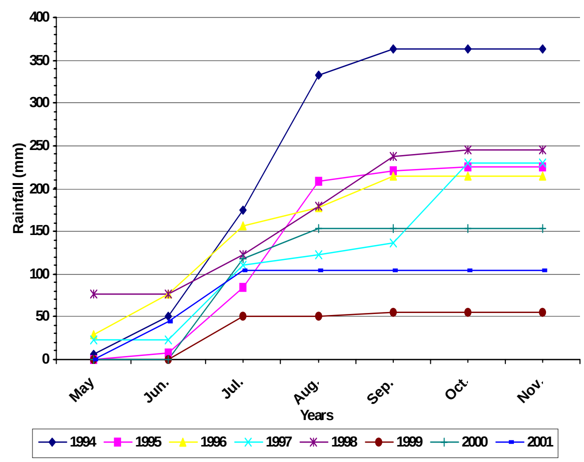


Fig. 3. Cummulative rainfall for the experimental years during the crop growth period



interval treatment were statistically at par during 1998. The plant heights remained almost the same during 2000 in the first three deep ploughed interval treatments compared with 1999 irrespective of the previous years treatments, and the differences among these treatments were found to be non-significant. During 2001 deep ploughing after every two and three years resulted in increased plant height compared with deep ploughing after every four and five year which in turn were statistically at par with each other. The shortest plants were again produced with the treatment that received shallow cultivation during this year. The results are in agreement with the findings of McConnel *et al.* (1989) who concluded that cotton plants grown in sub soiled areas were taller than those grown in non sub soiled areas.

Maximum plant height was recorded during 1994 and 1995 as compared to other years. This may be attributed to high precipitation received in these years during crop growth period.

Number of bolls per plant. Counts of mature, harvestable bolls just prior to harvest show substantial differences among the various deep ploughing interval treatments. (Table III). These differences ranged from a maximum of 50% to a minimum of 28% over and above the shallow cultivation. The eight years average data exhibited that the highest number of bolls per plant (29.2 bolls/plant) were recorded in plots deep ploughed after every two years as against the minimum of 19.5 bolls per plant with shallow cultivation, while the rest of the treatments provided intermediate bolls. The bolls per plant were similar with three and four years interval treatments. The findings of McConnell *et al.* (1989) are quite in agreement with these results.

The data further revealed that bolls per plant varied significantly with various deep ploughing interval treatments during all the years of study. During the initial phase of the study the number of bolls per plant were statistically non-significant upto 1997 unless and until the plots were deep ploughed again according to the treatment schedule. Non significant differences in the number of bolls per plant between deep ploughing every year and deep ploughing after two years were recorded during all the experimental years except 1995. Similar response was noted in four and five years interval treatment except 1998 and 1999.

It is evident from Table III that highest number of harvestable bolls (37.9 bolls/plant) was recorded during 1999. This might be due to the effect of minimum temperature that remained high during the months of boll formation as compared to other years (Fig. 3).

Seed cotton yield. The data given in Table IV showed highly significant differences in seed cotton yield among the various deep ploughing interval treatments. The averages of eight years yield data depicted that cotton planted in deep ploughing with two years interval treatment gave significantly the highest seed cotton yield of 1719 kg ha^{-1} as against the lowest of 1307 kg ha^{-1} in case of shallow

Table II. Heights of cotton plants (cm) as influenced by deep ploughing interval on sandy loam soil

Tr.	1994	1995	1996	1997	1998	1999	2000	2001	Average	%Inc.
T1	179.2a	186.0a	155.5a	110.1a	122.3a	159.1a	146.4a	139.4a	149.8a	22
T2	180.1a	176.3b	154.4b	102.2b	120.5a	149.4b	145.4a	133.3b	145.2b	19
T3	177.0a	177.9b	142.3b	107.5a	115.4b	140.4c	143.7a	134.4b	142.3c	16
T4	177.8a	175.4b	143.0b	96.5c	119.6ab	148.4b	131.2b	121.7c	139.2d	14
T5	175.9a	177.2b	140.5b	95.4c	106.5c	156.6a	134.1b	123.8c	138.8d	13
T6	162.5b	149.0c	127.4c	83.4d	101.3c	127.0d	118.3c	109.9d	122.4e	-
LSD	6.6	5.0	5.4	4.1	5.5	4.1	4.7	4.8	1.3	-
Average	175.4	173.7	143.9	99.2	114.3	146.8	136.5	127.1	-	-

Means followed by the same letter do not differ significantly at 5% probability level

Table III. Number of bolls per plant as influenced by deep ploughing interval on sandy loam soil

Tr.	1994	1995	1996	1997	1998	1999	2000	2001	Average	%Inc.
T1	23.1a	23.9a	26.8a	20.9a	34.9a	39.4ab	30.3a	26.4a	28.2b	45
T2	23.9a	21.1b	28.4a	21.6a	36.2a	42.2a	31.4a	28.9a	29.2a	50
T3	24.4a	20.2b	23.6b	22.4a	30.5b	34.5c	29.7a	25.1ab	26.3c	35
T4	24.1a	21.0b	24.0b	17.9b	35.8a	38.3b	25.1b	21.6c	26.0c	33
T5	23.3a	19.6b	23.2b	17.2b	25.7c	42.8a	25.5b	21.8bc	24.9d	28
T6	19.0b	14.5c	19.1c	13.3c	24.2c	30.4d	19.4c	16.4d	19.5e	-
LSD	1.4	2.4	1.8	2.9	3.5	3.43	2.91	3.05	1.0	-
Average	23.0	20.1	24.2	18.9	31.2	37.9	26.9	23.4	-	-

Means followed by the same letter do not differ significantly at 5% probability level

Table IV. Seed cotton yield (kg/ha) as influenced by deep ploughing interval on sandy loam soil

Tr.	1994	1995	1996	1997	1998	1999	2000	2001	Average	%Inc.
T1	1370a	1300a	1575a	1111b	2011a	2538b	1773ab	1673b	1669b	27
T2	1380a	1242b	1625a	1130b	2033a	2674a	1808a	1863a	1719a	33
T3	1392a	1228b	1472b	1228a	1799b	2118d	1735b	1623b	1574c	20
T4	1385a	1236b	1456b	1029c	2013a	2407c	1470c	1459c	1557c	19
T5	1374a	1222b	1481b	1008c	1408c	2689a	1507c	1480c	1521d	16
T6	1224b	1060c	1305c	850d	1383c	2078e	1230d	1329d	1307e	-
LSD	72.7	46.3	55.3	29.0	38.3	31.7	38.3	51.8	23.1	-
Average	1354	1215	1486	1059	1775	2417	1587	1571	-	-

Means followed by the same letter do not differ significantly at 5% probability level

Table V. Economic analysis of seed cotton yield as influenced by deep ploughing interval

Detail of the treatment	Yield kg/ha	Add. yield	Add. income	Add. cost	C.B.R.
T1=Deep ploughing every year	1669	362	9050	10864	1:0.83
T2=Deep ploughing after every two years	1719	412	10300	5432	1:1.90
T3=Deep ploughing after every three years	1574	267	6675	4074	1:1.64
T4=Deep ploughing after every four years	1557	250	6250	2716	1:2.30
T5=Deep ploughing after every five years	1521	214	5350	2716	1:1.97
T6=No deep ploughing (Shallow cultivation)	1307	-	-	-	-

Based on seed cotton @ Rs. 25.00 per kg during the year 2001, Cross chiseling @ Rs. 1358.00 per ha cultivation. The results further led to the conclusion that deep ploughing every year produced higher yield than deep ploughing with three and four years interval, however, the later treatments appeared to be equally good. The cotton plots deep ploughed after every fifth year produced the lowest yield among the various deep ploughing treatments. In general about 16 to 33% increase in seed cotton yield was observed with various deep ploughing treatments over the shallow cultivation. This increase in seed cotton yield are probably the results of the shattering of compacted subsoil layer through deep ploughing after appropriate intervals that might aids in better development of root system which would result in more nutrient and moisture availability for the plants. The superiority of deep ploughing once in a three years period has also been observed by Basker *et al.* (1995) in producing better seed cotton yield. The results are also in agreement with the findings of Spurgeon *et al.* (1978); Tupper and Musick (1985); McConnell *et al.* (1989) and Reeves *et al.* (1995) who concluded that deep ploughing was necessary to maximize cotton yield. However, the conclusions of the experiment are contrary to the findings of Tompkins *et al.* (1979), Tupper and Spurgeon (1981) and Ahmad and Haffar (1993) who suggested that cotton farmers should be devoted to shallow tillage practices only during land preparation to lessen the cost of production.

Seed cotton yield was significantly affected by the deep ploughing treatments during all the seasons of the study. The perusal of data presented in Table IV indicated that deep ploughing treatments revealed significant yield differences since the inception of the study. Plots deep ploughed during 1994 gave non-significant yield differences upto 1997 until they were deep ploughed again according to the schedule of deep ploughing interval. The data further revealed that cotton plots deep ploughed after every two years interval produced higher seed cotton yield than that ploughed every year during all the cropping seasons except 1995. Non significant yield differences were recorded between four and five years intervals except during 1998 and 1999.

$$\text{C. B. R.} = \frac{\text{Additional income}}{\text{Additional cost}}$$

The year 1999 out yielded the all other seasons by producing an average seed cotton yield of 2417 kg ha^{-1}. This might be due to the dry growing season and lowest precipitation received in this year as compared to other years (Fig. 3). During 1998, 2000 and 2001 an intermediate yields were recorded. This again might be due to low precipitation received in these years especially in 2000 and 2001, and there after variation in pest pressure on cotton crop during different years of the study.

Economic effect of deep ploughing interval. The best measure of the effects of any treatment is the net return received over and above the cost of applying the treatment. The efficiency of deep ploughing interval treatments can be determined from the cost benefit ratio comparing with shallow cultivation (Table V). The economic analysis showed that the highest return of 2.30 per unit expenditure relative to shallow cultivation was obtained with the deep ploughing after every four years interval followed by five years with a cost benefit ratio of 1:1.97 as against the minimum of 1:0.83 received by deep ploughing the cotton plots every year.

The results obtained from this study confirmed that traditional land preparation methods in the cotton fields using shallow cultivation produced the lowest yield as compared to deep ploughing. The deep ploughing of sandy loam soils after every two years was useful, however, the benefit was higher in deep ploughing with four years interval. It is therefore recommended that the farmers in the Thal and other areas with similar soil texture should deep plough the cotton fields during land preparation after every four years.

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