Chapter 51
Use of Conservation Tillage System in Semiarid Region to Ensure Wheat Food Security in Pakistan

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Abstract To help bridge the gap between food demand and supply, Pakistan requires an optimum, sustainable, and best adopted strategies to maintain the momentum of the agriculture sector. Investments need to be made in agricultural education, research and development, extension, soil and water resources, and allied infrastructural development which will lead to increase the food production and improve soil and water conservation. Wheat-rice cropping system in Pakistan, particularly in the areas where late-maturing fine-rice varieties are grown, the late-season harvesting of rice crop coupled with conventional land preparation leads to significant delay in wheat sowing and extra usage of irrigation water, and preparatory tillage operations result in a reduction in wheat yields. These practices not only increase the costs of production but also degrade the soil structure and organic matter availability. Conservation tillage technology including earlier wheat plantation, improved water use efficiency which can help to resolve this yield decline when compared with conventional tillage practices in both canal and ground water command areas. In an attempt to test these technologies, a comparative study on the soil and water conservation is tested using four wheat varieties in randomized complete block design (RCBD). Analysis revealed significant differences in all noted parameters including yield-contributing traits due to conservation tillage system compared to where this was not used. It was concluded that out of four exotic and local wheat varieties, the genotype Inqalab-91 proved best yielder in seedling as well as across tillage operation conditions. Additionally, the energy conservation was also done

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by adopting an integrated, holistic, and pragmatic approach to ensure staple food especially in competitive areas of semiarid regions.

Keywords Agriculture • Conservation • Conventional • Cost of production • Pragmatic approach

51.1 Introduction

Pakistan presents diversified topographic features including vast plains of fertile land. Most of the area remained under water stress due to lack of irrigation water and insufficient rainfall, even with average annual rainfall of 254–356 mm against the essential demand of 1,778 mm (Khan 2003). This condition leads to widening the gap between production and consumption (Anonymous 2007). Pakistan is facing a serious threat of rapidly growing population at the alarming rate of 2.7% per annum. It seems a dream that Pakistan had only 32.4 million peoples at the time of independence in year 1947. In the next five years, we saw a significant population increase to 138 million in 1952 and 170 million in 2010, and projectile population will be 208.06 million in year 2025 (PWP 2007).

To feed this burgeoning population, the pressure was exerted to local agriculture production having two cropping patterns, rice-wheat and cotton-wheat. The rice is grown on 2.2 million ha area, of which 62% area exists in Punjab province. In Punjab, most of farmers prefer to grow rice despite of low productivity and high delta of water, leading to 78 of rice area under fine-rice varieties enabling Punjab province to house 96% of total rice production in Pakistan (Sarwar and Goheer 2007). The rice-wheat cropping belt of Pakistani Punjab is considered as the food basket of fine grain length and aromatic rice, which contributes significantly toward the foreign exchange earnings and projects Pakistan throughout the world.

Wheat is another major crop best fitted in rice-wheat cropping system and has a prime position in national agricultural policies (FAO 2002). World food programs are under severe threats due to water scarcity, poor germination rates, less emergence rate, late sowing and harvest, and postharvest losses particularly in most of the Asian countries. These areas used almost 90% of total diverted fresh water for their agricultural needs (Huaqi et al. 2002).

Pakistan has a rich source of wheat germplasm having the ability to withstand water stress, drought, heat, and salt stress. In our crop improvement programs, the major problem is poor germination and late sowing or a combination of any two or three. Seedling trait is an important aspect which depicts the final crop stand. Various factors, such as seed germination, emergence, seedling vigor, energy of emergence, growth rate, mean emergence time, and water stress tolerance, exert their impact directly on the yield of a crop (Crosbie et al. 1980; Farooq et al. 2006). Due to late sowing, fulfilling physiological maturity periods and late harvesting of the crop rice-wheat cropping system are suffering significantly, depicting a low yield which is insufficient to feed burgeoning population (Iqbal et al. 2002). Due to this serious concern, wheat yields are affected badly, i.e., up to 50 kg ha^{-1} day^{-1} (Agriculture Information 2009).

Table 51.1 Area, production, and yield of wheat

Year	Area (000 ha)	Production (000 t)	Yield (kg ha^{-1})
2002–2003	8,034	19,183	2,388
2003–2004	8,216	19,500	2,375
2004–2005	8,358	21,612	2,568
2005–2006	8,448	21,277	2,519
2006–2007	8,578	23,295	2,716
2007–2008	8,550	20,959	2,451
2008–2009	9,046	24,033	2,657
2009–2010	9,042	23,864	2,639

Source: Ministry of Food and Agriculture, Federal Bureau of Statistics, Government of Pakistan

Looking at the ecosystem in broader perspective, it has a water cycle where addition of new water is impossible, and hence, we have to manage our agriculture within available resources. Definitely farmers and researchers are doing their best to find the possible ways to minimize the water use and to maximize the crop production with economical cost/benefit ratio in wheat production. It has also been shown that crop stand is improved in wheat if sown under conservation tillage operation system as compared to conventional systems of crop grown (Du et al. 2000).

The conservation tillage system is an improved and integrated approach to tackle the problem of wheat yield stagnation in the rice-wheat zone and to overcome late sowing, eliminating land preparation, direct seeding of next crop, and enhancing fertilizer application efficiency and consumptive use of water (Hammel 1995; Noorka et al. 2011). Conventional tillage is inducing deleterious effects on agriculture by increasing runoff, soil erosion, and nutrient depletion. In the changing face of climatic conditions, the conditions may even become worse. In comparison to conventional tillage, the conservation tillage avoids soil disturbance, improves soil moisture conditions, and improves soil structure (Jiao et al. 2004). To achieve maximum benefits, a conservation tillage technique is used to sow wheat after successful maturity of rice crop. This technique not only saves time but increases yield and improves soil quality and water saving (Rijsberman and Molden 2001).

According to the economic survey, the year-wise area, production, and yield of rice and wheat are increasing year by year in Pakistan (Table 51.1).

Keeping in view the shortage of irrigation water, increasing cost of inputs, and poor germination to compare the exotic and local germplasm, this study was initiated to explore increase in crops yields that may lead to bridge gap between supply and demand, a way forward to address food security for generations to come.

51.1.1 Conservation Tillage

The soil preparation for crop production is commonly accomplished by using mechanical and other means for plowing, digging, overturning, shoveling, hoeing, and raking. Small-scale farmers use conventional hand tools and often tools pulled by animals; however, farmers are now diverting their preferences toward the use of tractors and other machinery. The overall goal of conservation tillage is to increase crop production while conserving resources (soil and water) and protecting the environment (IBSRAM 1990). Conservation tillage, a progressive approach, presents innovative strategies and methods to tackle the remnants of ex-crop's residues, which can be used to get extra benefits, remained on the soil surface. This extra benefit depicts in slowing the water movement, which ultimately reduces the amount of soil erosion and nutrient depletion. Conservation tillage is suitable for a range of crops. Literature suggests there is great potential to use conservation tillage technology in Africa, Asia, and Eastern Europe, although limiting factors have to be taken into account (Derpsch 2001; GTZ 1998). The most common conservation tillage practices are no-tillage, ridge-tillage, and mulching-tillage. In fact, no-tillage is a way of growing crops without disturbing the soil as preparatory operation. This practice involves leaving the residue from last year's crop undisturbed and planting directly into the residue on the seedbed. Conversation tillage does not require specialized seeding equipment designed to plant seeds into undisturbed crop residues and soil. Cover crops – "green manure" – can be used in a conservation tillage system to help control weeds. Cover crops are usually leguminous which are typically high in nitrogen and have the ability to increase soil nitrogen. In ridge-tillage practices, the soil is left undisturbed for some period from harvest to planting, and then the crop is planted by making raised ridges. Planting usually involves the removal of the top of the ridge. Planting is completed with sweeps, cultivator, disk openers, and row cleaners. Residues are left on the surface between the ridges. Weeds are the serious threat to field crops and are controlled with cover crops, by applying herbicides and/or by integrated approach of hoeing and cultivation. Ridges are rebuilt in this process during row cultivation. Mulch-till technique involves soil disturbance between the times of harvesting of one crop and the planting of the next crop but leaving around a third of the soil covered with residues after seeding. Implements used for mulch-till techniques include chisels, sweeps, and field cultivators.

51.1.2 How the Technology Contributes to Climate Change Adaptation

Unpredictability of rainfall and an increase in the mean temperature may affect soil moisture levels leading to severe damages and the totally failures in crop yields. Conservation tillage practices reduce risk from drought by reducing soil erosion, enhancing moisture retention, and minimizing soil compaction. In combination, these factors improve resilience to climatic effects of drought and floods (Smith 2009). Improved soil nutrient recycling may also help combat crop pests and diseases (Holland 2004).

51.1.3 Advantages of Conservation Tillage

Conservation tillage benefits farming by minimizing erosion, increasing soil fertility, and improving yield. Plowing definitely loosens and aerates the soils which ultimately facilitate the roots to go deeper and deeper. Tillage is also believed to be helpful to boost up the growth of microorganisms and their mixing with crop harvest residues and soil organic matter. Conservation tillage helps the farmers to reduce fuel consumption as well as soil compaction and labor fatigue. In turn, this can increase time available for additional farm work or off-farm activities for livelihood diversification. Also once the system is established, requirement for herbicides and fertilizers can be reduced. According to Sorrenson et al. (1998), the total economic benefits as the outcome of no-tillage technique in small farms of generally less than 20 ha in Paraguay have reached around $941 million.

51.1.4 Disadvantages of Conservation Tillage

In case of conservation tillage operation, there are chances of weed infestation which require the application of herbicides, particularly in the transition phase, up to the establishment of the new balance of weed populations (Malik et al. 2000). The conservation tillage over a period of time may lead to soil compaction; however, this can be prevented with chisel plows or subsoilers. Initial investment of time and money along with purchases of equipment and herbicides will be necessary for establishing the system. There is a strong relationship between this technology and appropriate soil characteristics. This is detrimental in high clay content and compact soils.

51.1.5 Objectives

- To study soil and water conservation through conservation tillage in rice-wheat cropping system.
- To check the seedling behavior (germination percentage, emergence index, etc.) and yield response of four diverse wheat genotypes in conservation tillage compared to conventional tillage operation.
- To study the effect of different exotic and local wheat genotypes on the growth and yield under the given set of soil and water conditions.
- To demonstrate the value of innovative conservation technology to students and farmers through their active participation particularly at sowing and harvesting.

51.2 Materials and Methods

The study was conducted during 2008–2009 at the research area of the University College of Agriculture, University of Sargodha, Pakistan. The research station is situated in area known for rice-wheat cropping pattern. The agriculture and land use map of Pakistan is shown in Fig. 51.1a, presenting major rice growing areas in the provinces of Punjab and Sindh.

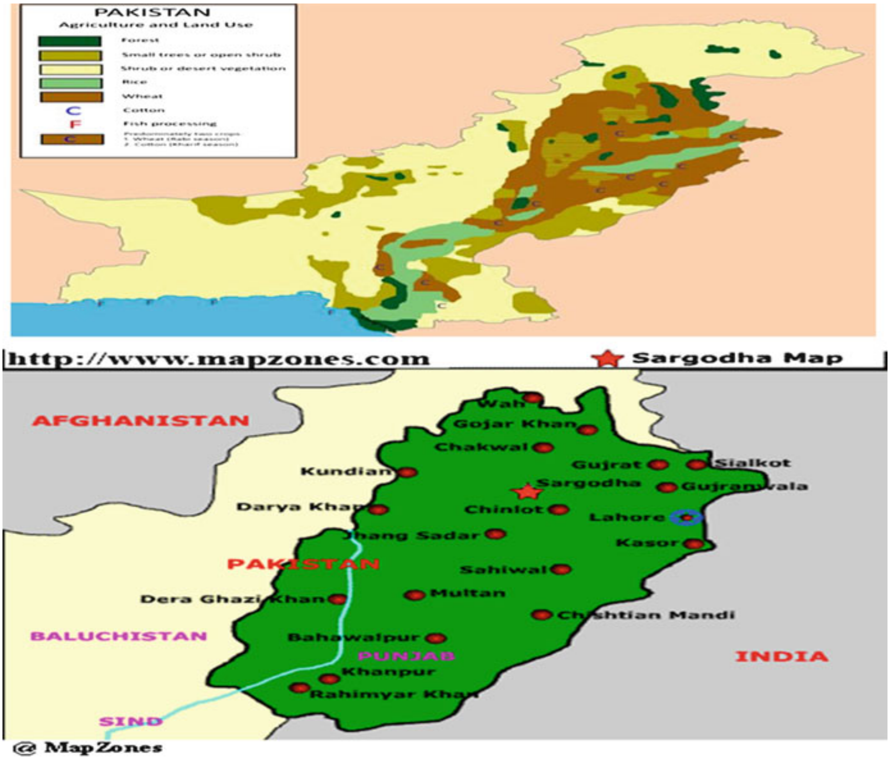

Fig. 51.1 (**a**) Map of Pakistan showing agriculture and land uses. (**b**) Map of Punjab showing Sargodha (experiment location). Courtesy of Map zones Pakistan

The Sargodha District lies at 32° 03′ N latitude and 72° 40′ E longitude and at an altitude of 187 m. Mean monthly maximum temperature varies from 20.2 to 41.7°C and minimum from 3.6 to 27.2°C. Mean annual rainfall in the area is about 435 mm. Wheat is a staple food predominantly grown in large area of Pakistan. The Punjab province of Pakistan is considered as the food basket; currently, Punjab shares 76.64% of total wheat production in Punjab (GOP 2010).

51.2.1 Soil Analysis of Experimental Area

The soil samples were collected from 0 to 15 cm, 15 to 30 cm, and 30 to 60 cm depths and analyzed using standard procedures (Chapman and Pratt 1961; Watanabe and Olsen 1962). Soil pH was measured in saturated soil paste (SSP) using pH meter, and electrical conductivity of soil saturation extract (ECe) was measured by standard EC meter and expressed as dS m^{-1}. The pHs is in neutral range (pH 7.15), and the soil was nonsaline (EC_e 0.28 dS m^{-1}) with very low organic matter content

(0.78%). Soil texture was determined by standard Bouyoucos hydrometer methods and % distribution of sand (2–0.05 m), silt (0.05–0.002 mm), and clay (<0.002 mm) determined. These values were then used on USDA textural triangle to determine soil textural class. Soil texture is sandy clay loam.

51.2.2 Experimental Details

The experiment is comprised of two treatments: (1) treatment 1 (T1) conservation tillage and (2) treatment 2 (T2) conventional tillage. In conservation tillage, the seeds were planted in existing rice field after harvesting without removing stubbles and plowing the fields. Seeds were sown with hand-pore drill due to plot being in small size. In conventional tillage, the rice field was plowed and then seeds were sown with hand-pore drill as used in conservation tillage.

Four diverse exotic and local wheat varieties, namely, Nesser (V1), Inqalab-91 (V2), Sarsabz (V3), and Sehar-08 (V4), were used in a randomized complete block design (RCBD) with three replications in a plot (6 m×6 m) for both treatments. The sowing was accomplished on 15 November 2008. Prior to sowing, the seeds were treated with fungicide Vitavex-200 @ 0.25% to protect from soilborne diseases. Seeds were sown by hand-pore drill. Plant-to-plant distance (2 cm) was maintained by thinning.

Urea, single super phosphate (SSP), and sulfate of potash (SOP) were used as source of NPK nutrients, respectively. The fertilizers were applied at the recommended rates to both the treatments (NPK 52:46:25 kg ha^{-1}) (GOP 2010). One-third of urea, full dose of SSP, and SOP fertilizers were broadcasted before sowing the wheat crop, while the remaining two doses of urea were used at tillering stage (22 days after planting the wheat) and flowering and grain making stage (90 days after planting).

The canal irrigation water was applied to both treatments. Three irrigations were given, first at 22 days after sowing (when seedling phase data was recorded) and the second at 60 days and third after 90 days after sowing. The flooded irrigation method was used to irrigate the experimental area. From each plot, ten plants are selected randomly at initial and maturity stages. The traits (plant height, number of tillers per plant, spike length, number of grains per spike, grain yield per plant) were recorded and analyzed statistically (Tables 51.2–51.4).

During the seedling phase, only one row of each treatment and each replication was selected. A total of 200 seeds per line were sown. Data collection was started immediately upon the emergence of first seedling in any of the plot. The counting/measurements were made on daily basis at 1,600 h for instant updates, and a number of visible seedlings were recorded. Data collection remained continued until there was no further emergence of the seedling. The trait emergence percentage was calculated according to the formula given by Smith and Millet (1964) and Noorka and Khaliq (2007):

$$\text{Emergence (\%)} = \frac{\text{Total number of seedlings emerged 18 DAS} \times 100}{\text{Total number of seedlings grown}}$$

Table 51.2 Wheat genotypes and their origin

Genotype	Origin of genotype
V1 = Nesser	CIMMYT, Mexico
V2 = Inqalab-91	Punjab Province, Pakistan
V3 = Sarsabz	Sindh Province, Pakistan
V4 = Sehar	Punjab Province, Pakistan

where DAS = Days after sowing.

Emergence index (EI) is the estimate of emergence rate of seedlings, which was calculated as per AOSA (1983):

$$EI = \frac{\text{No. of seeds emerged at first count} + \cdots + \text{No of seeds emerged at final count}}{\text{Days of first count} + \cdots + \text{days of final count}}$$

The emergence rate index for each treatment and replication was calculated as follows:

$$ERI = \frac{\text{Emergence Index}}{\text{Emergence percentage}}$$

The energy of emergence was computed according to the method outlined by Ruan et al. (2002). It is the percentage of emerged seedlings 3 days after sowing.

The mean emergence time was calculated in accordance with the equation of Ellis and Roberts (1981) as below:

$$MET = \frac{\Sigma Dn}{\Sigma n}$$

where n is the number of seeds germinated on day D and D is the number of days counted from the beginning of emergence.

51.3 Results and Discussion

Among the one exotic and three local genotypes, the emergence percentage ranged between 82.40 and 90% under conservation tillage (T1), while in conventional tillage (T2) operation, the emergence percentage was 80.95–91.50%. Maximum value of emergence index was depicted by the genotypes Inqlab-91 (6.879) while minimum (5.623) in genotype Nesser in conservation tillage, while under conventional operation, maximum emergence index was depicted by the genotype Sarsabz (6.753). The data is illustrated in Table 51.3.

A magnitude of variability was observed in all seedling traits like energy of emergence and mean emergence time in both conditions (Table 51.3).

Table 51.3 Mean values of emergence percentage (EP), emergence index (EI), emergence rate index (ERI), energy of emergence (EOE), and mean emergence time (MET) in days at seedling phase

Treatments	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
Genotypes	EP	EP	EI	EI	ERI	ERI	EOE	EOE	MET	MET
Nesser	90.00	89.50	5.623	5.745	0.062	0.062	46.67	44.54	1.996	2.001
Sarsabz	82.50	80.95	6.694	6.753	0.081	0.083	44.33	45.23	1.943	1.998
Inqalab 91	87.90	90.20	6.879	6.457	0.078	0.071	50.00	52.12	1.919	1.897
Sehar	82.40	84.60	5.850	6.564	0.070	0.077	43.76	43.96	1.945	1.945

T_1 conservation tillage and T_2 conventional tillage

Earlier and rapid emergence was observed in genotypes with maximum energy of emergence and emergence rate index (Noorka et al. 2007). In both conditions, the genotype Sarsabz and Inqalab-91 gained top position for emergence rate index and energy of emergence, respectively. A relationship was found among emergence percentage, emergence index, energy of emergence, and mean emergence time. The higher the emergence percentage, emergence index and energy of emergence and lower mean emergence time indicated earlier and rapid germination of the genotype. In this experiment, the genotype Inqalab-91 remained at the top by securing maximum emergence percentage in conventional tillage, emergence index under conservation tillage, maximum energy of emergence, and minimum mean emergence time under both tillage operation techniques. These findings are supported by similar findings (Zheng et al. 1994; Nayyar et al. 1995; Noorka and Khaliq 2007; Hameed et al. 2010).

To differentiate cost and benefit and associated morphological traits and tillage operation system, data from both conservation tillage and conventional tillage were used. The mean data on growth and yield traits are given in Table 51.4.

Table 51.4 illustrates significant difference among genotypes. Both treatments showed most of the yield, and yield-contributed traits behaved best in conservation tillage operation. It was noted that direct sowing of wheat in the rice stubbles has minimized the time invested to prepare the seedbed preparation, water used to do preparatory irrigation (locally called *Rouni*), tillage operation, energy in shape of tractor, and tube well diesel through conservation techniques. The results are also supported by other researchers (Aslam et al. 1993; Du et al. 2000; Iqbal et al 2002).

All genotypes showed significant difference under both tillage operations. Plant height is an important trait for crop improvement. The shorter the height, the plant will be best suited to bear climatic conditions as well as contribute better to crop yield. Most of the genotypes achieved maximum height in conventional tillage as compared to conservation tillage. Among genotypes, the exotic (CIMMYT) genotype Nesser showed minimum plant height and second best yielder under both tillage conditions. In this way, T1 (conservation tillage) behaved better compared to T2 (conventional tillage).

Regarding the number of tillers per plant, the genotype Sehar-08 attained maximum number of tillers per plant under T1, while Inqalab-91 attained maximum number of tillers per plant under T2 condition. As the treatments are concerned, T1 (conservation tillage) once again performed well as compared to T2 (conventional tillage) by topping three genotypes. In spike length measurement, the exotic genotype Nesser ranked number one under T1, while the genotype Sarsabz attained maximum spike length under T2 conditions.

In case of the treatments' performance, T1 (conservation tillage) and T2 (conventional tillage) remained equal. The exotic genotype Nesser attained maximum number of grain per spike in both tillage operations; however, T1 (conservation tillage) performed the best than T2 (conventional tillage).

The genotype Sehar attained maximum thousand grains weight in T1, while in T2, the genotypes Nesser showed best performance; however, T1 (conservation

Table 51.4 Comparative mean values of morphological traits under conservation and conventional tillage of four diverse wheat genotypes at maturity stage

Treatments	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
Genotypes	PH	PH	NT	NT	SL	SL	NGS	NGS	TGW	TGW	GY	GY
Nesser	85.80	93.87	9.45	7. 40	13.33	12.04	52.30	49.50	25.38	31.01	21.10	20.60
Sarsabz	104.50	100.50	9.50	9.30	11.90	12.80	48.90	44.76	26.43	25.65	14.90	15.50
Inqalab-91	97.50	106.04	11.02	11.40	12.50	10.30	44.30	40.80	22.83	21.54	22.66	18.00
Sehar-08	101.30	105.50	11.25	11.00	11.02	11.90	44.90	41.32	28.90	28.50	22.30	21.34

T_1 conservation tillage, T_2 conventional tillage, plant height (PH) in cm, no. of tillers/plant (NT), spike length (SL) in cm, no. of grains/spike (NGS), 1,000-grain wt (TGW) in grams, grain yield/plant (GY) in grams tillage) and T2 (conventional tillage) performed similarly. The grain yield per plant has prime importance for farmers; the genotype Inqalab-91 attained maximum grain yield per plant in T1 condition, while under T2 condition, Nesser remained at top. Overall the T1 (conservation tillage) once again performed better compared to T2-conventional tillage.

In general, the performance of Inqalab-91 proved the best in both tillage operations. Today's agriculture is going very costly. The poor farmers are not able to afford much agricultural costs particularly in tillage operation and seed selection. If germplasm is properly screened we can select the best genotype whose emergence percentage and mean emergence time will be outstanding. In the same way, conservation tillage is taking momentum. It is adopted by the farmers so that they can avoid 4–5 land preparation cultivation which costs almost 3,500–4,000 Pakistani rupees (38–43 US$) per acre. Additionally, soil structure is also disturbed, organic matter is exposed and dried at high temperature in summer, and the microbial population is disturbed that have deleterious effects on soil properties leading to poor land services for agriculture.

As discussed earlier, the wheat cultivation time was delayed mainly due to late harvesting of rice. If the conservation tillage operation system is adopted, then timely sowing of wheat may be done. It is a best sign in agriculture that farmers are going to prefer conservation tillage. Earlier researchers (Uri et al. 1999; Holland 2004) reported that conservation tillage reduced runoff and erosion and improved the soil structure. By less cost, maximum hazards of environment can be overruled. The results of this study revealed that crop stand is improved for wheat under conservation tillage. The conservation tillage technology is increasing the crop production and net income of farmers, given the condition that it is properly used by the farmers and area under conservation tillage will increase to ensure food security (Jeffrey et al. 2002; Zhanxing 2008).

51.4 Conclusions

It is concluded that farmers and eco-friendly policies are needed to provide economical ways to farming communities for land preparation to achieve high yields and conserving their precious soil resources ultimately paving the way forward to ensure food security, through bridging the gap between national food demand and supplies. Conservation tillage system creates such a type of sustained and most appropriate soil environment to the crops to get maximum growth of a crop that may conserve soil and water, save energy resources by minimizing the intensity of tillage to minimize structure destruction, and preserve plant residues for beneficial outcomes. This study concluded that emergence and related attributes criteria have vital role to discriminate the genotypes as well as treatments (tillage operation). This study also revealed that exotic and local wheat varieties showed diverse behavior to different tillage operation systems. The genotype Inqalab-91 proved best and can play a significant role in meeting food demand. However, further research is needed to transfer the findings to other areas where conditions similar to Sargodha semiarid zones may be existing in other parts of Pakistan.

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