

# EFFECT OF STRIP CROPPING, CONSERVATION TILLAGE AND LAND MANIPULATION ON CROP PRODUCTION OF GREEN GRAM AND SORGHUM

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## Abstract

Agricultural productivity in Pothwar region of Pakistan is limited due to prolonged dry periods followed by high intensity rainfall, soil degradation and water loss in form of runoff. Avoiding summer fallowing when intensive rain showers are received can decrease runoff. New farming systems designs are required to maximize productivity by mitigating erosion and decreasing runoff. The effect of strip cropping and contour ploughing on leveled slope and undisturbed soil in terms of crop productivity was evaluated. The field study was conducted at University Research Farm Koont, Chakwal road Rawalpindi. Land slope (S1: Slope  $\leq$  5%, S2: Land Leveling  $\leq$  0.5%), conservation tillage (T1: ploughing along the slope, T2: Contour Ploughing along the contour line and across the slope) and strip cropping (C1: Sole Cereal, C2: Sole Legume C3: Cereal + Legume, (Sorghum + Green Gram) were studied in RCBD in split-split plot arrangement for two consecutive years i.e., 2016 and 2017. The collected data were subjected to Fisher's Analysis of Variance and means were separated by LSD at  $\alpha=0.05$ . The investigation showed that tillage practices adopted for seed bed preparation and sowing of seed influenced the rate of soil and water loss from the field. Both slope manipulation and strip cropping improved crop productivity. However, strip cropping with legumes further increased productivity due to N fixation. Tillage practices done across the slope obstructed the water ways that decreased runoff. Farming systems that minimized soil disturbance, maximized ground cover reduced erosion and increased productivity equivalent to mechanical slope manipulation. Inclusion of legume strips across the slope was a technology that mitigated erosion and enhanced productivity. Adoption of the technology is expected to reduce downstream silting up.

**Index Terms:** Plant density, Strip cropping, Vigna radiata, Sorghum bicolor, Slope Manipulation, Topography, Contour tillage, conservation agriculture

## 1. INTRODUCTION

Agriculture is a leading sector in the economy of Pakistan. Most of the people in our country depend upon agricultural sector in different ways. It has 19.53 % of share in our GDP, employs 42.3% of the total work force, and 60% of the population in our rural areas earn their livelihood through it [1]. Soil is naturally eroded by the action of water or wind:

for millions of years this kind of 'history' (or 'geological') soil erosion has occurred. Background erosion destroys soil at about the same rate at which it is produced, but 'accelerated' soil erosion is a much more recent concern arising from human activities such as overgrazing or improper cultivation practices. Accelerated soil erosion is one of the most common environmental issues today and can impact both agricultural areas and the natural environment. It has consequences both on site and off site [2].

Soil loss typically means loss of topsoil that contains the most organic matter and nutrients and has the most attractive structure of soil. The annual loss may be as high as 300 metric tons per hectare (2.5 cm), meaning that in 6-7 years the entire plough layer would be lost. Geological erosion, on the other hand, which is around 0.2-0.5 t ha<sup>-1</sup> year<sup>-1</sup> and something greater than 10 t ha<sup>-1</sup> year<sup>-1</sup>, is considered a significant soil problem [3]. Soil erosion from cultivated areas is a land management issue and can be influenced by agricultural management options (Cerdà et al., 2009). All available erosion control measures include: conservation agriculture (including reduced tillage and no-till farming, suitable cropping, mulching, cover crops, strip cropping, contour ploughing, the installation of vegetative buffers and strips, and terracing [4].

It is probable that various cropping systems are more robust to externalities and less reliant on external inputs [5]. Strip Cropping divides the field into strips of different crops to reap from rotations the same beneficial results recognized [6]. Production of various crops may be enhanced through strip cropping systems due to their better growth rate, reduction in the population of insects, pests, weeds, fungal diseases as well as efficient utilization of available resources [7].

Integration of cereal with legumes not only improves the quality of cereal crops but it also raises the nutritional value of crop residues, feeding stuffs and animal production [8]. The N fixed by legumes in intercropping system, during their joint growing time, it is transferred to cereals and becomes an essential cereal resource [9]. Pulses are rich source of protein for human diet as well as improve the soil fertility through nitrogen fixation. There is decline in Pulses (Green Gram) cultivated area in Pakistan by 2.7% during 2014-15. United Nation has declared 2016 as the year of pulses. Production of pulses is affected by many biotic and abiotic stresses which hamper the realization of actual yield potential [10]. Green gram (*Vigna radiate* L.) is a best short-duration and drought tolerant summer legume crop of Pakistan. It is important to poor as it supplies substantial amount of protein (Spa). Green gram seeds have a total protein content of 24.20 percent, total fats of 1.30 percent and total carbohydrates of 60.4 percent, with seed levels of Ca and P of 118 and 340 mg/100 g respectively [11].

Green gram is successfully grown twice in a year in rain-fed and irrigated areas of the country with either autumn or spring cultivation [12]. The total area under its cultivation is 135.90 thousand hectares; with total annual production of 90.00 thousand tons and grain yield of 662.25 kg/ha [13]. The basic reasons behind its limited yield are inadequate water supply, poor soil fertility status, attack of insect, pest and diseases and weed infestation. Sorghum is a major summer cereal crop, currently ranked fourth after maize, wheat and rice respectively in Pakistan. It is being cultivated for the purpose of grain for human,

feed for poultry and fodder for livestock on irrigated as well as rain-fed areas of the country.

Soil erosion is a major threat to soil resources; approximately  $2.2 \text{ T ha}^{-1} \text{ yr}^{-1}$  of arable topsoil is lost in the UK due to water erosion [14]. Erosion rates in most of Europe vary from  $<1$  to  $20 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  [15] in comparison to the soil formation rates from  $0.3$ - $1.4 \text{ Mg}^{-1} \text{ ha}^{-1} \text{ yr}^{-1}$ . Van Kessel & Hartley [16] reported that sustainability in agricultural production and also the long-term productivity of food crops can be ensured by biological fixation of atmospheric nitrogen. Legumes help in the fixation of  $\text{N}_2$  which is effectively capitalized by the following factors: (i) efficiency of the symbiotic relationship between rhizobia and host plant, (ii) the effectiveness of sink, (iii) total N available from soil and (iv) different environmental hazards to the fixation of atmospheric nitrogen hence improves soil organic matter contents.

## 2. MATERIAL AND METHODS

The geographical location of field trial lies at latitude  $33.1166^\circ \text{ N}$ ,  $73.0111^\circ \text{ E}$  (University Research Farm Chakwal road Rawalpindi, a district of the Punjab province, Pakistan). Experiment was laid out in Randomized Complete Block Design with Split-Split Plot arrangement keeping slope in main plots, conservation tillage in sub plots and strip cropping in sub-sub plot. Sub-Sub plot size was  $6 \text{ m} \times 3 \text{ m}$ . Each treatment comprised three replications. R-R and P-P distance was maintained in accordance with the cereals / legumes standard agronomic practices. The general protocol of experiment (cultural practices and plant protection measure etc.) was same according to the general recommendations and specific crop requirement.

### Treatments

#### Factor A (Land Slope)

**S<sub>1</sub>:** Slope  $\leq 5\%$

**S<sub>2</sub>:** Land Leveling

#### Factor B (Conservation Tillage)

**T<sub>1</sub>:** Ploughing along the Slope.

**T<sub>2</sub>:** Ploughing across the Slope (Contour Ploughing).

#### Factor C (Strip Cropping)

**C<sub>1</sub>:** Cereal sole

**C<sub>2</sub>:** Legume Sole

**C<sub>3</sub>:** Cereal + Legume

For this purpose suitable field with required slop  $\leq 5\%$  was selected and a portion part of it was leveled using farm machinery. Land slop was our factor A in the main plot. The field portion left as it is was our treatment S<sub>1</sub> and 2nd leveled half was our treatment S<sub>2</sub>. Factor B was in sub plot and it was treated in two ways. First treatment T<sub>1</sub> was cultivation or

tillage across the contour line and along the slope. In it all the tillage practices seed bed preparation and etc. were done along the slope and in the 2<sup>nd</sup> treatment T<sub>2</sub> tillage practices were done across the slope and along the contour. 3<sup>rd</sup> factor was strip cropping in sub-sub plot and in it crops were sown in strips. These strips were of the single crop or two crops one after the other. It was partitioned in three treatments, in first treatments C<sub>1</sub> strips of sorghum were sown, in C<sub>2</sub> there were strips of green gram only and C<sub>3</sub> was strips of cereals and legumes.

Alternate Strips of cereal and legume crops were sown in C<sub>3</sub>. Each strip was comprised of 5 rows of cereal/legume. Strip of crops were sown each after 5 rows of one crop at alternate pattern. Strip direction remained constant in each plot. All the growth, yield and quality parameters were recorded by using standard principles and procedures. For statistical analysis, data collected on various aspects were subjected to Fisher's Analysis of Variance Technique (ANOVA) using statistical package "Statistix 10"(www.statistix.com, e-mail: sales@statistix.com). After analysis of variance Fisher's protected LSD test was applied to compare the means. Means were compared at 5 % level of probability for significance.

### 3. RESULTS AND DISCUSSION

#### Sorghum Grain Yield:

In the 1st year the seed yield of Sorghum was significantly affected by field slope and direction of crop rows. Cropping patterns (strips or sole crop) were also significant during the 1st year of trial. In the 2nd year land leveling, crop's row direction and cropping pattern had significant effect on seed yield of sorghum. The interactions, i.e., slope × row orientation, row orientation × cropping system and slope × row orientation × cropping system were non-significant during both the years. Over all during the 2nd year sorghum grain yield was increased. Planting across the slope performed better during the following year and confirmed the results of 2016. The leveling of land increased the yield of sorghum in both the years significantly was attributing to run off control leading to increased nutrient and water availability. Water and nutrient loss from cultivated areas is a land management issue and can be influenced by agricultural management options like slope manipulation [17].

Across the slope sowing showed significant effect on seed yield of sorghum. Across the slope tillage practices intercept runoff and increase infiltration. Nutrients retention in the crop roots zone was improved and higher moisture level in the soil made these nutrients available to the plants to rapidly boost the growth ultimately increasing economic yield. The increase in final seed yield was due to better nutrient availability to the crop [18], [19]. The sorghum grown in alternate strips with green gram produced better seed yield than sole crop. It might be because both the crops had different rooting habit exploring different soil profile for nutrients and water thus facing less crop competition. Another reason could be interception of rainfall in strips of cereal and legume resulted in reduced impact of rainfall on detachment of soil particle indicating that strip cropping is more beneficial on sloppy lands for conservation of soil, crop nutrients and water [20].

## **Sorghum Biological Yield**

Analysis of variance regarding biological yield ( $\text{kg ha}^{-1}$ ) of sorghum revealed that field slope, row orientation and strip cropping were significant, while the interactions were non-significant during the 1st year. The sorghum in strips produced significantly higher biological yield as compared to sole sorghum in 2016. During the 2nd year land leveling, crop row orientation significantly increased biological yield of sorghum. Sorghum-green gram strip cropping increased sorghum biological yield as compared to mono cropping in 2nd year. The two-way interactions i.e., slope  $\times$  row orientation, row orientation  $\times$  cropping system were non-significant and the three way interactions between slope  $\times$  row orientation  $\times$  cropping system were significant in the 2nd years. In 2017 interaction of leveled field, tillage practices across the slope and strip cropping gave maximum yield and the sloppy field where sole sorghum was sown along the slope gave minimum yield. It was noted that higher biological yield of sorghum was obtained from the leveled field but the field where land was not leveled and crop was sown in strips across the slope gave yield at par the leveled field. In the year's comparison biological yield was increased during 2nd year as compared to 1st year. Better biological yield was obtained from leveled field it might be because of controlled soil erosion. Just like leveled field, across the slope sowing also increased yield significantly in both years. Maintenance of plant cover across the slope is particularly vital among the different factors involved in obstructing the water ways [21], [22].

Strip cropping also showed significant effect on biological yield of sorghum. Strip Cropping divides the field into strips with different crops to gain the same positive effects that of rotations [23]. The interactions among slope, sowing direction and strip cropping were significant in the 2nd year and showed that maximum biological yield was obtained from leveled field which was ploughed across the slope and sorghum was sown in strips with legume. High yield in strip cropping might be due to the avoidance of inter specific root competition for nutrients and water to the same soil depths which is supported by [24]. The diverse cropping systems are likely to be more resilient to externalities and less dependent on external inputs [25].

## **Green Gram Grain Yield**

In the 1st year the seed yield of green gram was significantly affected by field slope and direction of crop rows. Cropping patterns (strips or sole crop) were non-significant during the 1st year of trial. In the 2nd year land leveling, crop's row direction and cropping pattern had significant effect on seed yield of green gram. The interactions, i.e., slope  $\times$  row orientation, row orientation  $\times$  cropping system and slope  $\times$  row orientation  $\times$  cropping system were non-significant during both the years. Over all during the 2nd year green gram yield was increased. Although during first year the green gram seed yield under sole and strip crop was statistically same but in the subsequent year it was increased under strips. Planting across the slope performed better during the following year and confirmed the results of 2016.

The leveling of land increased the yield of green gram in both the years significantly was attributing to run off control leading to increased nutrient and water availability. Water and

nutrient loss from cultivated areas is a land management issue and can be influenced by agricultural management options like slope manipulation [26]. Across the slope sowing showed significant effect on seed yield of green gram. Across the slope tillage practices intercept runoff and increase infiltration. Nutrients retention in the crop roots zone was improved and higher moisture level in the soil made these nutrients available to the rapidly to boost growth ultimately increasing economic yield. The increase in final seed yield was due to better nutrient availability to the crop [27].

The green gram grown in alternate strips with sorghum produced better seed yield than sole crop. It might be because both the crops had different rooting habit exploring different soil profile for nutrients and water thus facing less crop competition. Another reason could be interception of rainfall in strips of cereal and legume resulted in reduced impact of rainfall on detachment of soil particle indicating that strip cropping is more beneficial on sloppy lands for conservation of soil, crop nutrients and [28].

### **Green Gram Biological Yield**

Analysis of variance regarding biological yield ( $\text{kg ha}^{-1}$ ) of green gram revealed that field slope, row orientation and strip cropping were significant, while the interactions were non-significant during the 1st year. The green gram in strips produced significantly higher biological yield as compared to sole green gram in 2016. During the 2nd year land leveling, crop row orientation significantly increased biological yield of green gram. Sorghum-green gram strip cropping increased green gram biological yield as compared to mono cropping in 2nd year. The two-way interactions i.e., slope  $\times$  row orientation, row orientation  $\times$  cropping system were non-significant and the three-way interactions between slope  $\times$  row orientation  $\times$  cropping system were significant in the 2nd years. In 2017 interaction of leveled field, tillage practices across the slope and strip cropping gave maximum yield and the sloppy field where sole green gram was sown along the slope gave minimum yield. It was noted that higher biological yield of green gram was obtained from the leveled field but the field where land was not leveled and crop was sown in strips across the slope gave yield at par the leveled field. In the year's comparison biological yield was increased during 2nd year as compared to 1st year.

Better biological yield was obtained from leveled field it might be because of soil erosion. Just like leveled field, across the slope sowing also increased yield significantly in both years. Maintenance of plant cover across the slope is particularly vital among the different factors involved in obstructing the water ways [29], [30]. Strip cropping also showed significant effect on biological yield of green gram. Strip cropping on sloppy field gave yield ( $3426 \text{ kg ha}^{-1}$ ) that was statistically non-significant with the leveled field. Strip Cropping divides the field into strips with different crops to gain the same positive effects that of rotations [31].

The interactions among slope, sowing direction and strip cropping were significant in the 2nd year and showed that maximum biological yield ( $4005.3 \text{ kg ha}^{-1}$ ) was obtained from leveled field which was ploughed across the slope and green gram was sown in strips with cereal. High yield in strip cropping might be due to the avoidance of inter specific root competition for nutrients and water to the same soil depths which is supported by [32].

**Table 1: Effect of slope manipulation and strip cropping on grain yield (kg ha<sup>-1</sup>) of sorghum**

Treatment		Main Means							
		2016				2017			
Slope	Natural Slope $\leq 5\%$ ( $S_1$ )	2908.3B				3085.1B			
	Manipulated Slope $\leq 0.5\%$ ( $S_2$ )	3671.9A				3802.6A			
Row Orientation	Along the Slope ( $T_1$ )	2959.7B				3741.6A			
	Across the Slope ( $T_2$ )	3620.4A				3146.0B			
Cropping System	Sole Sorghum ( $C_1$ )	3086.4B				3253.5B			
	Strip ( $C_3$ )	3493.8A				3634.1A			
Interaction	Year	$S_1T_1C_1$	$S_1T_1C_3$	$S_1T_2C_1$	$S_1T_2C_3$	$S_2T_1C_1$	$S_2T_1C_3$	$S_2T_2C_1$	$S_2T_2C_3$
Slop*RO*CS	2016	2321.0	2767.7	2982.0	3562.3	3165.7	3584.7	3877.0	4060.3
Slop*RO*CS	2017	2476.5	3002.0	3234.5	3627.2	3389.1	3716.6	3913.8	4190.8

Means showing different letters in respective columns/rows differ significantly at  $\alpha=0.05$

**Table 2: Effect of slope manipulation and strip cropping on biological yield (kg ha<sup>-1</sup>) of sorghum**

Treatment		Main Means							
		2016				2017			
Slope	Natural Slope $\leq 5\%$ ( $S_1$ )	20129 B				20486B			
	Manipulated Slope $\leq 0.5\%$ ( $S_2$ )	23696A				24164A			
Row Orientation	Along the Slope ( $T_1$ )	20696B				21054B			
	Across the Slope ( $T_2$ )	23129A				23597A			
Cropping System	Sole Sorghum ( $C_1$ )	21116A				21376B			
	Strip ( $C_3$ )	22709B				23274A			
Interactions	Year	$S_1T_1C_1$	$S_1T_1C_3$	$S_1T_2C_1$	$S_1T_2C_3$	$S_2T_1C_1$	$S_2T_1C_3$	$S_2T_2C_1$	$S_2T_2C_3$
Slop*RO*CS	2016	17903	19499	20691	22422	21805	23578	24063	25338
Slop*RO*CS	2017	17975D	19980CD	21171BCD	22817ABC	22019BC	24241AB	24340AB	26058A

Means showing different letters in respective columns/rows differ significantly at  $\alpha=0.05$

**Table 3: Effect of slope manipulation and strip cropping on grain yield (kg ha<sup>-1</sup>) of green gram**

Treatment		Main Means							
		2016				2017			
Slope	Natural Slope $\leq 5\%$ ( $S_1$ )	907.0B				923.5B			
	Manipulated Slope $\leq 0.5\%$ ( $S_2$ )	1061.5A				1085.6A			
Row Orientation	Along the Slope ( $T_1$ )	922.5B				945.2B			
	Across the Slope ( $T_2$ )	1046.0A				1063.8A			
Cropping System	Sole Green Gram ( $C_2$ )	967.2A				957.4B			
	Strip ( $C_3$ )	1001.4A				1051.6A			
Interactions	Year	$S_1T_1C_2$	$S_1T_1C_3$	$S_1T_2C_2$	$S_1T_2C_3$	$S_2T_1C_2$	$S_2T_1C_3$	$S_2T_2C_2$	$S_2T_2C_3$
Slop*RO*CS	2016	848.6	844.6	930.6	1004.2	980.5	1016.3	1108.9	1140.3
Slop*RO*CS	2017	858.5	891.3	920.4	1023.6	938.3	1092.7	1112.4	1199.0

Means showing different letters in respective columns/rows differ significantly at  $\alpha=0.05$

**Table 4: Effect of slope manipulation and strip cropping on biological yield (kg ha<sup>-1</sup>) of green gram**

Treatment					Main Means				
					2016		2017		
<b>Slope</b>	Natural Slope $\leq 5\%$ ( <b>S<sub>1</sub></b> )				2872.3B		2993.0B		
	Manipulated Slope $\leq 0.5\%$ ( <b>S<sub>2</sub></b> )				3520.3A		3727.2A		
<b>Row Orientation</b>	Along the Slope ( <b>T<sub>1</sub></b> )				2943.6B		3121.9B		
	Across the Slope ( <b>T<sub>2</sub></b> )				3448.9A		3598.3A		
<b>Cropping System</b>	Sole Green Gram ( <b>C<sub>2</sub></b> )				3064.0B		3199.4B		
	Strip ( <b>C<sub>3</sub></b> )				3328.5A		3520.8A		
<b>Interactions</b>	<b>Year</b>	<b>S<sub>1</sub>T<sub>1</sub>C<sub>2</sub></b>	<b>S<sub>1</sub>T<sub>1</sub>C<sub>3</sub></b>	<b>S<sub>1</sub>T<sub>2</sub>C<sub>2</sub></b>	<b>S<sub>1</sub>T<sub>2</sub>C<sub>3</sub></b>	<b>S<sub>2</sub>T<sub>1</sub>C<sub>2</sub></b>	<b>S<sub>2</sub>T<sub>1</sub>C<sub>3</sub></b>	<b>S<sub>2</sub>T<sub>2</sub>C<sub>2</sub></b>	<b>S<sub>2</sub>T<sub>2</sub>C<sub>3</sub></b>
<b>Slop*RO*CS</b>	<b>2016</b>	2531.5	2750.4	2916.2	3291.1	3107.2	3385.4	3701.3	3887.2
<b>Slop*RO*CS</b>	<b>2017</b>	2771.2C	2804.5C	2970.5C	3425.9AB	3064.9BC	3847.3 A	3991.2 A	4005.5 A

Means showing different letters in respective columns/rows differ significantly at  $\alpha=0.05$

#### 4. CONCLUSION

The present study led to the conclusion that inclusion of legumes in the form of strips across the slope results in the saving of energy and cost of production on one hand and help in the control of erosion on the other.

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