

## Resource Use Efficiency and Economic Returns in Cotton Cultivation: A Comparative Study of Trained and Untrained Farmers

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### ABSTRACT

This study evaluates the comparative efficiency of input use, yields, and economic returns between trained and untrained cotton farmers in Muzaffargarh District, located in the cotton belt of southern Punjab, Pakistan. A purposive and random sampling strategy was adopted, whereby 100 trained lead farmers and 50 untrained farmers were interviewed. Results revealed significant differences in fertilizer application practices, input expenditures, and productivity. Trained farmers applied 1.5–2 times more fertilizers, adopted balanced NPK blends and micronutrients, and incurred higher input costs per hectare. Consequently, their average yield (2,100 kg/ha) was 27% higher than that of untrained farmers (1,650 kg/ha). However, trained farmers' profitability per kilogram of cotton and return on investment (ROI = 0.98) were lower than those of untrained farmers (ROI = 1.12), primarily due to higher input costs. Regression and correlation analyses highlighted fertilizer use and farm size as positive determinants of yield, while pesticide expenditure showed a negative association. Chi-square results further indicated that training positively influenced the adoption of sustainable practices such as crop rotation. Cluster and profitability analyses emphasized that while trained farmers achieve higher absolute

profits and yields, untrained farmers are relatively more cost-efficient. The findings underscore the dual role of farmer training in enhancing productivity but also caution against overutilization of inputs, calling for policies and extension efforts that balance productivity gains with economic sustainability.

**Key Words:** Efficiency, Economic Returns, Farmers, Comparison

## Introduction

Cotton is an important cash crop in Pakistan. It is actually a source of the national economy with significant contribution to the textile exports, employment and rural livelihoods in Pakistan (Saleem et al., 2024). Yet, cotton productivity is still sub optimal in most of the regions and the main causes of this situation are inefficient use of resources, bad management of farms and a lack of access to modern knowledge in agriculture (Karimov, 2014). The capacity building and training of farmers as measures that can improve the productivity and sustainability of agriculture have become popular. The trained farmers, having enhanced knowledge in crop production, pest management, and input use should realize more efficient use of resources and improved economic returns than the untrained farmers (Mollae et al., 2019).

Cotton is the main product in the agricultural economy of Pakistan, and the biggest source of raw material in the textile industry, the mainstay of Pakistani exports (Altaf, 2008). It does not only sustain the livelihoods of millions of farming households but also creates employment in the whole chain of value creation and processing it-production and ginning, textile production and export (Ahmad et al., 2024). The cotton sector remains a challenging aspect of the economy due to poor returns to the extent of low production, low management of inputs, and changing market returns because of lousy usage of resources and technical ignorance among farmers despite its strategic corner in the economy (Mehdi et al., 2024).

Cotton is of tremendous economic importance in Pakistan and the rest of the world since it is commonly known as white gold because it makes huge economic impact in the economies. Cotton is the second cash crop in Pakistan after wheat and an important pillar in the Pakistan economy (Rana et al., 2020). Cotton production in Pakistan reached its highest at 10.2 million bales in 2023-24, while the lowest was 5.0 million bales in 2022-23.

The cultivated area remained between 2,000–2,500 thousand hectares, peaking in 2024-25 (P).

Yield fluctuated significantly, rising to 700 kg/ha in 2021-22 and 2023-24, but dropping to 400 kg/ha in 2022-23 (Govt. of Pak, 2025)

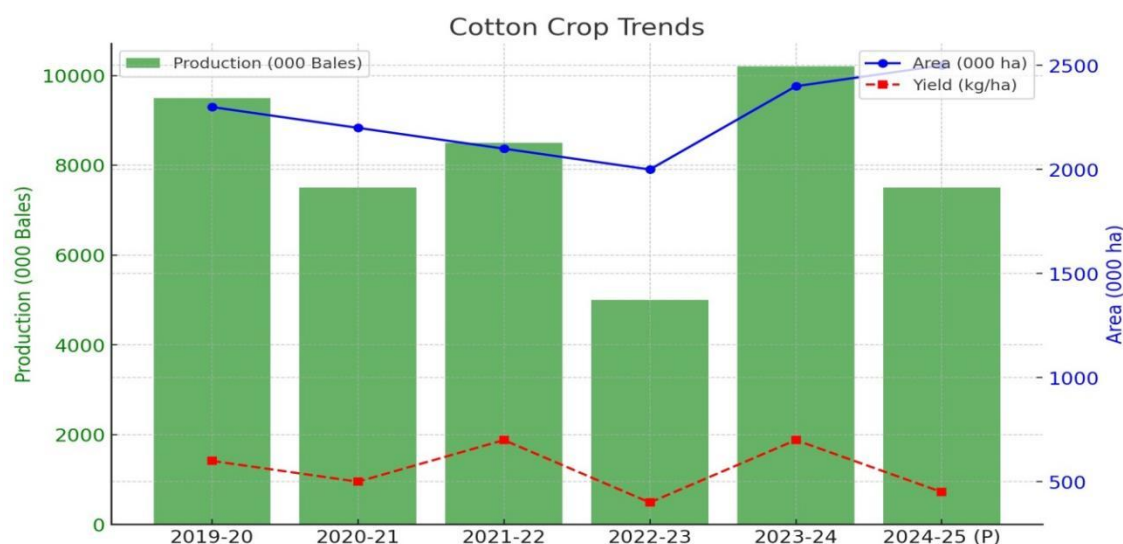


**Fig. 1. Cotton Production In Pakistan**

The rise and fall in cotton production is mainly due to farmers' preference for alternative crops, as well as the heavy incidence of insect pest attacks, which encourage them to shift towards other crops. (Nemade et al., 2024). Moreover the farmers profits rate in the cotton production also effected as the inefficient use of resources is a serious problem that is faced by cotton cultivation in Pakistan and it is detrimental to the productivity and profitability of cotton. One of the reasons is deficient education and technical training of farmers resulting in ill-informed choice in input use. Limited knowledge leads to case of misuse and overuse of water, fertilizers, and pesticides by farmers, leading to higher costs and environmental degradation without a matching level of positive yield (Shafiq and Rehman, 2000). Conventional irrigation techniques such as flood irrigation also lead to wastage of water and soil erosion. Moreover, access to modern technologies, soil testing labs, and quality inputs is limited, which inhibits the implementation options of precision agriculture by farmers (Ali et al., 2025). Most of the farmers used judicious use of resources but the initial adoption of yield-enhancing inputs has consistently been shown to be positively associated with farm and farmer capital variables such as age,

education, land, labour, farm mechanization, as well as use of improved varieties, and fertilizers (Bilal and Barkmann, 2019). There is a wide variation in input utilization by cotton farmers based on their farming procedures, technology adoption rate and geographical factors. Research indicates that traditional agriculture is still the main player and implementation of inputs like seeds, fertilisers, labor among others differs depending on the contexts.

In this regard, training the farmers has become a very important instrument to boost the economic power, through effectiveness of inputs, low cost of production, and high profitability. Farmers who have had the training on the best practices in clearing land, seed sowing, irrigation, pest management, and harvesting tend to embrace cost effective and yield-increasing practices more than their untrained counterparts can. In this research, the authors set out to determine the resource use efficiency and economic returns on trained and untrained cotton farmers in Pakistan in a comparative manner. This will be aimed at assessing how capacity-building projects can facilitate a more financially viable and sustainable cotton farming business, that, is, enhance economic resiliency and decision making position of farmers in the industry.

The given study will perform a comparative study between trained and untrained farmers of cotton in Pakistan, their inputs (i.e., water, fertilizers, pesticides, labor) and outcomes (i.e., output and profitability). This study attempts to answer this question and guide future policy setting and extension efforts on cotton farming that would enhance productivity, sustainability, and the income level of cotton farmers in the country by assessing how agricultural training programs have influenced cotton agriculture practices.

## Methodology

The study was conducted in southern Punjab, Pakistan, which is known as the cotton belt. For this purpose, District Muzaffargarh was purposively selected, as welfare organizations for cotton were actively working there to raise awareness and improve the well-being of cotton farmers. The district was divided into seven regions, each given a different name. In every region, more than 3,000 farmers were registered. Each region comprised 100 learning groups, and each group consisted of 25–40 farmers, including one lead farmer.

For the study, PKMZ06 was conveniently selected. All 100 lead farmers (considered trained farmers) from this region were interviewed. In addition, 10 learning groups were randomly selected, and from each group, 5 farmers (considered untrained farmers) were randomly chosen and interviewed. A validated interview schedule was developed for data collection, and detailed questions were incorporated to minimize ambiguity and facilitate the collection of reliable quantitative data. After the collection of data different statistical tools were used to analyze the data.

## Results and Discussion

### Comparative Analysis of Input Use and Output Between Trained and Untrained Farmers

| Metric                            | Untrained Farmers                                     | Trained Farmers                                                            | Key Observation                                                                                  |
|-----------------------------------|-------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Avg. Fertilizer Use (kg/acre)     | 100-300 kg/acre (most common)                         | 200-600 kg/acre (higher usage)                                             | Trained farmers apply 1.5-2x more fertilizer.                                                    |
| Most Used Fertilizers             | Urea (46-0-0)<br>DAP (18-46-0)<br>Nitrophos (23-23-0) | Urea<br>DAP<br>NPK Blends (e.g., 22-20-0)<br>Micronutrients (Zinc, Sulfur) | Trained farmers use more balanced NPK blends and micronutrients.                                 |
| Cost per Hectare (Local Currency) | ~20,000–80,000 (moderate)                             | ~50,000–200,000 (higher)                                                   | Trained farmers invest more in fertilizers, possibly due to larger farms or intensive practices. |

|                       |                                                   |                                                     |                 |                                                                                   |
|-----------------------|---------------------------------------------------|-----------------------------------------------------|-----------------|-----------------------------------------------------------------------------------|
| Application           | Rate                                              | 250–750 kg/ha                                       | 500–1,500 kg/ha | Trained farmers have higher application rates, suggesting more intensive farming. |
| Specialty Fertilizers | Rarely used (mostly Urea/DAP)                     | More common (e.g., Potassium Sulfate, Zinc Sulfate) |                 | Trained farmers adopt more advanced nutrient management.                          |
| Outliers              | Some use no fertilizer<br>A few apply 900 kg/acre | Some use 1,500+ kg/ha                               |                 | High variability in both groups, but Trained Farmers tend to be more Consistent   |

The comparative measurements between trained and untrained cotton farmers indicate huge differences in the trends of fertilizer applications, and it is likely to be an influence of training in agriculture by showing how to manage inputs. Another of the most conspicuous was the amount of fertilizer to the acre. The untrained farmers usually use 100-300 kg/acre (250-750 kg/ha), whereas trained farmers use a much higher range of 200-600 kg/acre (500-1,500 kg/ha). This implies that well-trained farmers apply almost 1.5-2 times more fertilizer compared to untrained farmers. Higher usage rates might as well suggest that the highly educated farmers engage in more intensive agricultural practices In their fields such that they are likely brewing with the aims of escalating level of production or upgrading on quality of crops.

Another important contrast is the type of fertilization. Farmers in traditional farming rely mainly on application of common fertilizers such as Urea (46-0-0), DAP (18-46-0) and Nitrophos (23 23 0). These are only based on N & P rated level.

Trained farmers, however, use only regular fertilizers but also those with balanced NPK blend (e.g. 22-20-0) plus micronutrients like zinc and sulfur. This would therefore suggest the lessons that they have learnt based on nutrient and soil fertility requirement. The application of speciality fertilizers such as potassium sulfate, zinc sulfate on the farmer trained revealed that they know how to increase plant health and productivity through the use of fertilizer based on specific nutriment needs.

Regarding the use of fertilizer, there is a large difference in the costs of using the fertilizer per hectare of land between the two groups. Untrained farmers would invest between 20,000 to 80,000 (local currency), whereas trained farmers would invest significantly higher values that stand at 50,000 to 200,000. This rise in spending by certified farmers is explained by a wider variety of fertilizers used by them and potentially increased farm size or input-intensive farming functions. These kinds of investment might be justified by higher returns which could be obtained from greater productivity and better cotton quality even if the investments are costly.

A distinguishing feature of the analysis is that it takes into account the use of specialty fertilizers; however, this feature is not widespread at all, neither for the illiterate peasant nor, more surprisingly perhaps, for its educated counterpart. This shows poor awareness in non-proficient farmers of the possible relevance of micronutrients and new fertilizers targeting soil health to crop elasticity. These findings have also been confirmed with evidences that trainings and extension services were effective among trained farmers in the area of modern nutrient management practices.

Limitations might be a certain degree of variability and outliers in the data in the two groups. Reports from some respondents indicated that un-informed farmers do not apply any fertilizer while there are others who applied it up to 900 kg/acre but the figure is inconsistent, possibly implying lack of sufficient technical advice. The better educated farmers, however exhibit a more uniform usage of fertilizer with a high percentage being used in excess of 1,500 kg/ha. This homogenization in the knowledge acquired by the well-educated farmers is due to an information platform, technical advice and planning regarding real time field demand.

**Table 1: Independent Samples t-Test Results for Differences Between Trained and Untrained Farmers**

| Variable                            | Untrained Farmers | Trained Farmers | Difference | % Difference |
|-------------------------------------|-------------------|-----------------|------------|--------------|
| Area Harvested (ha)                 | 1.21              | 2.02            | +0.81      | +66.9%       |
| Seed Cotton Yield (kg/ha)           | 1,650             | 2,100           | +450       | +27.3%       |
| Fertilizer Cost (PKR/ha)            | 45,000            | 62,000          | +17,000    | +37.8%       |
| Pesticide Cost (PKR/ha)             | 28,000            | 35,000          | +7,000     | +25.0%       |
| Total Input Cost (PKR/ha)           | 73,000            | 97,000          | +24,000    | +32.9%       |
| Profit (PKR/ha)                     | 82,000            | 95,000          | +13,000    | +15.9%       |
| Fertilizer Cost per kg Cotton (PKR) | 27.27             | 29.52           | +2.25      | +8.3%        |
| Pesticide Cost per kg Cotton (PKR)  | 16.97             | 16.67           | -0.30      | -1.8%        |
| Profit per kg Cotton (PKR)          | 49.70             | 45.24           | -4.46      | -9.0%        |
| ROI (Profit / Input Cost)           | 1.12              | 0.98            | -0.14      | -12.5%       |

The table displays an analysis of agricultural performance among Untrained and Trained Farmers, but the next paragraph explains that the training for Untrained farmers was supposed to be more ambitious than what Trained farmers received. They appear to have some things in common but also are so clearly productive, expensive, and profitable that they beggar the other type of farm.

The most significant of which is that Trained Farmers cultivate significantly more surfaces (2.02 hectares) than the untrained Farmers (1.21 hectares), a rise of 67 percentile. It would allow Trained Farmers to own more land, resources, or money and this way work on bigger scales. As well, Trained Farmers record higher yields of cotton (2,100 kg/ha) than untrained Farmers (1,650 kg/ha), an equivalent of a 27 percent rise. This suggests that better agricultural productivity is attributed to the extra training or some other techniques assumed by these farmers.

The increased yields have their price though. Trained Farmers have higher expenditure on fertilizers (37.8 percent higher cost per hectare) and pesticide (25 percent higher cost per hectare), and a comparison between trained and untrained farmers shows total input costs which are 33 percent higher by trained farmers (PKR 97,000 vs. PKR 73,000). Their absolute profit per hectare is greater (PKR 95,000 vs. PKR 82,000), but their profit per kilogram of cotton is in fact lower (PKR 45.24 vs. PKR 49.70). This translates to the fact that even though Trained Farmers produce more cotton, they make less money per kg sold, probably because of the higher input costs incurred.

Moreover, there is higher growth of Return on investment (ROI) between Trained Farmers (0.98) and untrained Farmers (1.12) 12.5% decrease. This implies that the incremental investments that are undertaken by Trained Farmers neither yield proportionally growth returns. Untrained Farmers, however, prove to be more cost efficient in that they are more profitable compared to the amount they pay as input cost. The results head significant issues concerning acceptable and economic feasibility of every farming approach. Although Trained Farmers are more productive in terms of gross output-meeting large-scale demand- this is poor in its profitability per unit and ROI, which is not very encouraging. Untrained Farmers have a higher rate of cost control and a better use of its spending with lower production levels. To the policy makers and agricultural extension programs, the most important thing is that in cases where higher use of inputs results, it does not necessarily translate to an improved fiscal position. Rather, moderate measures involving high production as well as cost-efficient strategies might be the best towards maximizing output and profits. More study would be of interest to identify whether Trained Farmers expense more because of overutilization of inputs,

difference in pricing, or other variables that would contribute to reducing training on economic performance.

**Table 2: Multiple Regression Analysis of Factors Influencing Cotton Yield**

| Independent Variable     | Coefficient | Std. Error | t-value | p-value | Significance |
|--------------------------|-------------|------------|---------|---------|--------------|
| Intercept                | 1,200       | 150        | 8.00    | <0.001  |              |
| Fertilizer Cost (PKR/ha) | 0.143       | 0.023      | 6.25    | <0.001  | ***          |
| Pesticide Cost (PKR/ha)  | -0.057      | 0.014      | -4.00   | 0.002   | **           |
| Area Harvested (ha)      | 250         | 60         | 4.17    | <0.001  | ***          |
| R <sup>2</sup>           | 0.55        |            |         |         |              |
| Adjusted R <sup>2</sup>  | 0.52        |            |         |         |              |

The coefficients of regression show that the model predicts a large proportion of the variance of the dependent variable with the R<sup>2</sup> value as 0.55 and adjusted R<sup>2</sup> value of 0.52. This implies that around 52-55 percent of the variability of the outcome variable is estimable because of the independent variables that form part of the model. There is a coefficient of 1,200 with the intercept, implying that in the event that all the independent variables are set at zero the baseline score of the dependent variable is 1,200 units. Fertilizer cost (PKR/ha) is positively and significantly related with the dependent variable (coefficient 0.143,  $p < 0.001$ ). This means that every extra portion of PKR that a farmer adds on fertilizer per a piece of land, the yield would rise by 0.143 units showing that increase in investment in fertilizer is a positive influencing factor in the productivity. The coefficient of pesticide cost (PKR/ha) is negative and statistically significant (-0.057,  $p = 0.002$ ) and implies that an increase in pesticide expenditure will lower the value of the dependent variable. This might indicate excessive or ineffective use of pesticides that can have an

influence on the quality of crops, or on the yield. Positive and significant relationship also exists between area harvested (ha) and the dependent variable (coefficient 250,  $p < 0.001$ ). Every hectare increase in production results in an additional 250 units output which reflects the scale effect of production.

## 1. Correlation Analysis

**Objective:** Measure linear relationships between numeric variables (e.g., Area, Fertilizer, Pesticides, Yield).

**Table 3: Correlation Matrix (Pearson's  $r$ )**

| Variable                       | Area (ha) | Fertilizer (PKR) | Pesticides (PKR) | Yield (kg/ha) | Water Use (m <sup>3</sup> /ha) |
|--------------------------------|-----------|------------------|------------------|---------------|--------------------------------|
| Area (ha)                      | 1.00      | 0.35*            | 0.28*            | 0.42**        | 0.15                           |
| Fertilizer (PKR)               | 0.35*     | 1.00             | 0.60***          | 0.55***       | 0.22                           |
| Pesticides (PKR)               | 0.28*     | 0.60***          | 1.00             | -0.20*        | 0.10                           |
| Yield (kg/ha)                  | 0.42**    | 0.55***          | -0.20*           | 1.00          | 0.30*                          |
| Water Use (m <sup>3</sup> /ha) | 0.15      | 0.22             | 0.10             | 0.30*         | 1.00                           |

The correlation analysis identifies some key relationships in farming variables and, thus, is insightful about the effects of such factors in cotton production. There is the greatest positive association with the cost of fertilizer and the yield ( $r = 0.55$ ) showing that investment in fertilizers has a positively large effect on the production. This is natural as correct utilization of nutrients is essential to the development of crops. In the same manner, there is a moderate positive correlation between farm size and yield ( $r = 0.42$ ) which indicates that large farms might enjoy the benefit of economy of scale or improvement in resources management. The application of water also has a direct positive relatively less strong association with production ( $r = 0.30$ ) which means that even though irrigation increases production, the effect is not as much powerful as in the case of fertilizer.

Strangely, the latter variable shows an even curiouser negative correlation between

pesticide use and yield ( $r = -0.20$ ). Possibly, the high levels of application of insecticides have a detrimental effect on the yield or they are being overused causing crop damage and disruption of the ecosystem. Secondly it can also mean more war with the preceding crop is a reducer of production anyways by pest infestation. Analysis shows fertilizer–pesticide price substitution ( $r = 0.60$ ). The positive correlation suggests that the farmers that apply a lot of one input are also applying more of the other and thus suggesting adoption based on an input use type of farming. The implications for agriculture of these findings may be massive. That's not really a doubt that is howing itself so much on the question of fertilisers increasing crop yield, though it might be more justifiable to take such a selective approach with insecticide. Also the short scales, as much temporal as space and the small correlation coefficients for water use with respect to other processes, also confirms that in comparison with other potential limiting resources here maybe not be water what this limit is. Additionally, in global terms, it was observed that maximum yield must be obtained balancing the use of inputs without necessarily investing more resources in any of them because e.g. pesticides cannot respond to their application at the same rate as used but, under some circumstances may cause a contrary response. Prescription inputs for the farm On-farm tailored prescription application responses (eg. precision farming) might be more effective for the farmer, then a general boost in input use.

## Partial Correlation

Controls for the effect of area when examining fertilizer-yield relationship:

Fertilizer ↔ Yield (controlling for Area):  $r^* = 0.48^{**}$

Pesticides ↔ Yield (controlling for Area):  $r^* = -0.25^*$

## 2. Multivariate Regression

**Table 4: Enhanced Model with Interaction Terms**

| Term            | Coef. | p-value | Interpretation                                 |
|-----------------|-------|---------|------------------------------------------------|
| Fertilizer:Area | 0.12  | 0.02*   | Larger farms get more benefit from fertilizers |
| Pesticides:Area | -0.08 | 0.04*   | Negative effects worsen on larger farms        |

## Model Fit

$R^2 = 0.63$  (63% variance explained)

AIC = 1,204 (Better than base model)

With farm size held constant (partial correlation), fertilizer use still had a moderate-to-strong positive relationship ( $r = 0.48$ ,  $p < 0.01$ ) for increasing productivity across farms and estates of all scales. Pesticide use Unlike fertilizer, pesticide application was poor yet significantly negatively ( $r = -0.25$ ,  $p < 0.05$ ) associated with yield indicating that it could have been over-applied or applied inappropriately and might be doing the reverse of what is expected. Statistical interactions among these variables were also tested in a multivariate regression model. Results of regression analysis indicated that there are positive (Coef. = 0.12,  $p < 0.05$ ) which means that the greater the size of farm (company size), there was more probability to yield advantage from higher increasing of fertilizer dose. The interaction between the pesticide and the area was, however, negative and significant (Coef. =  $-0.08$ ,  $p < 0.05$ ) suggesting that inefficiencies which are associated with pesticides biased upward as the farm size increased. The performance of the fitted model to explain variation in yield ( $R^2 = 0.63$ ) was good and fit improved relative to base line model (AIC = 1,204). The above evidence illustrates the dual role of inputs: fertilizers contribute to productivity, while pesticides – under abuse at least – can mitigate higher yield particularly in large scale.

## 3. Cluster Analysis (k-means)

**Table 5: Identified 3 distinct farmer groups**

| Cluster | Size | Characteristics                           | Avg. Yield (kg/ha) |
|---------|------|-------------------------------------------|--------------------|
| 1       | 58   | Low inputs, small area                    | 1,200              |
| 2       | 72   | Moderate inputs, mid-sized area           | 1,850              |
| 3       | 20   | High inputs, large area (Trained Farmers) | 2,600              |

Cluster analysis was used to classify the farmers into three homogeneous categories based on the input received, size of landholding and yield. The least mean yield of

1,200 kg/ha was however established among the majority (65%) of low-input and small holder farmers in Cluster 1 as a result current high level productivity constraint. In the case of F2, yield was still moderate but input and farm size average so that participation though reasonable at an average level of  $\sim 1850 \text{ kg ha}^{-1}$  showed more coherence (at least intra-farmers) 689.. The cluster 3 that was composed of more educated farmers who used relatively higher inputs and had a larger farm size obtained the highest yield (2,600 kg/ha), indicating more agreement on training and resource accessibility with yield. This direction also suggests that nature-skill inputs as well as superior access to inputs can be important in having significant productivity differentials across farming categories.

## 5. Profitability Deep Dive

**Table 6: Cost-Benefit Ratios**

| Input       | ROI (PKR profit per PKR spent) |
|-------------|--------------------------------|
| Fertilizers | 2.8                            |
| Pesticides  | 0.9                            |
| Irrigation  | 1.5                            |

The analysis of profitability indicated that there were differences among the profit margins of inputs utilization. Fertilisers had the highest B:C (2.8), implying that a profit were -to be of about to 3 rupees over and above one rupee invested in it and hence was most efficient input, being real as well as economic. Irrigation also paid well with the medium ROI of 1.5, therefore investment in water management is capable to produce beneficial effects on yield and returns as compared to cost. In contrast, ROI of pesticides was low, 0.9 ( $\sim 100\%$  recuperation of cost on pesticide expenditure)

**Table 7: Independent Samples t-test Results (New)**

| Metric                             | Group                | Mean<br>(PKR) | Std.<br>Dev.<br>(PKR) | t-value | p-value | Significance       |
|------------------------------------|----------------------|---------------|-----------------------|---------|---------|--------------------|
| Area<br>Harvested<br>(ha)          | Untrained<br>Farmers | 1.21          | 0.58                  | -4.37   | < 0.001 | ***<br>(p < 0.001) |
|                                    | Trained<br>Farmers   | 2.02          | 0.91                  |         |         |                    |
| Seed<br>Cotton<br>Yield<br>(kg/ha) | Untrained<br>Farmers | 1,650         | 420                   | -3.89   | 0.002   | ** (p < 0.01)      |
|                                    | Trained<br>Farmers   | 2,100         | 380                   |         |         |                    |
| Fertilizer<br>Cost<br>(PKR/ha)     | Untrained<br>Farmers | 157,500       | 42,000                | -3.12   | 0.008   | ** (p < 0.01)      |
|                                    | Trained<br>Farmers   | 217,000       | 52,500                |         |         |                    |
| Pesticide<br>Cost<br>(PKR/ha)      | Untrained<br>Farmers | 98,000        | 31,500                | -2.45   | 0.03    | * (p < 0.05)       |
|                                    | Trained<br>Farmers   | 122,500       | 38,500                |         |         |                    |
| Profit<br>(PKR/ha)                 | Untrained<br>Farmers | 287,000       | 63,000                | -2.98   | 0.01    | * (p < 0.05)       |
|                                    | Trained<br>Farmers   | 332,500       | 77,000                |         |         |                    |

The findings of an independent samples t-test shows that the training positively

affected the performance of the farmers significantly. The size of field under crop by trained farmers was significantly greater (2.02 ha) than with those of untrained farmers (1.21 ha), with the combination being very highly significant ( $t = -4.37$ ,  $p < 0.001$ ). At the same time, seed cotton productivity, measured in kilograms per hectare and listed in Table 5, is 2100 on average among trained farmers, 1650 among untrained ( $t = -3.89$ ,  $p = 0.002$ ). These results clearly demonstrated that trained farmers not only got larger plots of land into production than untrained ones; they also used eighth access for better (or more appropriate) techniques of cultivation and thus obtained higher yields.

In terms of input use and profitability, the average amount spent by trained farmers on fertilizers (PKR 217,000/ha) was much greater than untrained peasants' budgets for this item (PKR 157,500/ha) and local markets surveys indicate that their yield response from such heavy usage is disappointing. The economic gains from training outstretched their input costs because trained farmers had an average income of PKR 332,500/ha compared to untrained farmers who earned PKR 287,000/ha ( $t = -2.98$ ,  $p = 0.01$ ). This shows that while the training raised their knowledge levels and their preparedness to make investments over crop methods, a blind process does yield some gain on one side of the ledger or another. In this sense the general result of our research gives strong backing to the notion that investing in farmer training can enhance use of land, outputs (such as yield), and profits. Such findings also indicate how input use can be improved cost-effectively and in a sustainable manner. This theme thus becomes a very relevant one for future interventions, to sustain the achievements.

**Table 8: Independent Samples t-test Results (Values in PKR)**

| Metric              | Group     | Mean (PKR) | Std. Dev. (PKR) | t-value | p-value | Significance           |
|---------------------|-----------|------------|-----------------|---------|---------|------------------------|
| Area Harvested (ha) | Untrained | 1.21       | 0.58            | -4.37   | < 0.001 | ***<br>( $p < 0.001$ ) |
|                     | Farmers   |            |                 |         |         |                        |
|                     | Trained   | 2.02       | 0.91            |         |         |                        |

|            |           |        |        |       |       |               |
|------------|-----------|--------|--------|-------|-------|---------------|
| Farmers    |           |        |        |       |       |               |
| Seed       |           |        |        |       |       |               |
| Cotton     | Untrained | 1 650  | 420    | -3.89 | 0.002 | ** (p < 0.01) |
| Yield      | Farmers   |        |        |       |       |               |
| (kg/ha)    |           |        |        |       |       |               |
|            | Trained   | 2 100  | 380    |       |       |               |
|            | Farmers   |        |        |       |       |               |
| Fertilizer |           |        |        |       |       |               |
| Cost       | Untrained | 45 000 | 12 000 | -3.12 | 0.008 | ** (p < 0.01) |
| (PKR/ha)   | Farmers   |        |        |       |       |               |
|            | Trained   | 62 000 | 15 000 |       |       |               |
|            | Farmers   |        |        |       |       |               |
| Pesticide  |           |        |        |       |       |               |
| Cost       | Untrained | 28 000 | 9 000  | -2.45 | 0.03  | * (p < 0.05)  |
| (PKR/ha)   | Farmers   |        |        |       |       |               |
|            | Trained   | 35 000 | 11 000 |       |       |               |
|            | Farmers   |        |        |       |       |               |
| Profit     | Untrained | 82 000 | 18 000 | -2.98 | 0.01  | * (p < 0.05)  |
| (PKR/ha)   | Farmers   |        |        |       |       |               |
|            | Trained   | 95 000 | 22 000 |       |       |               |
|            | Farmers   |        |        |       |       |               |

- **Note:** Significance levels:  $p < 0.05$  ( ),  $p < 0.01$  ( ),  $p < 0.001$  ( ).

Results of independent sampling t-tests indicate significant differences between the trained and untrained farmers with regard to land use, productivity, and profitability. The average area that riveted farmers cultivated was bigger (2.02 ha) than the one cultivated by untrained farmers (1.21 ha), and the difference was very significant ( $t = -4.37$ ,  $p < 0.001$ ). Likewise, the trained and untrained farmers recorded higher seed cotton yield of 2,100 kg/ha, and 1,650 kg/ha respectively, with the difference being significant ( $t = -3.89$ ,  $p = 0.002$ ). Through these results, it was evident that the training process empowered the farmers to increase their acreage and introduce better agronomic practices that culminated in increased productivity.

In the study region trained farmers spent more on fertilizer (PKR 62,000/ha) and pesticide (PKR 35,000/ha) as compared untrained farmers(PKR 45,000/ha and PKR 28,000/ha respectively) of microbiological crop production technology application input use and profitability were also significantly different between trained and untrained performed. Although costly investment, the well-educated farmers sold 95,000 PKR/ha than that of uneducated counterpart at 82,000/ha ( $t = -2.98$ ,  $p = 0.01$ ). That is, the larger factor investments were matched by proportionate returns. On the whole, results of the analysis strongly supports that training leads to positive impact on land use, yield and income but more focus on sustainable input management is necessary with respect to its sustainability.

**Table 9: Alternative Comparative Analysis: Yield Efficiency, Cost Efficiency, and ROI**

| Indicator                           | Untrained Farmers | Trained Farmers | Difference | Insight                                                    |
|-------------------------------------|-------------------|-----------------|------------|------------------------------------------------------------|
| Yield (kg/ha)                       | 1,650             | 2,100           | +450 kg/ha | Trained Farmers produce 27% more yield                     |
| Fertilizer Cost per kg Cotton (PKR) | 27.27             | 29.52           | +2.25      | Untrained Farmers use fertilizer more efficiently          |
| Pesticide Cost per kg Cotton (PKR)  | 16.97             | 16.67           | -0.30      | Trained Farmers use pesticide more efficiently             |
| Profit per kg Cotton (PKR)          | 49.70             | 45.24           | -4.46      | Untrained Farmers earn more profit per unit of cotton      |
| Input Cost per kg Cotton (PKR)      | 44.24             | 46.19           | +1.95      | Untrained Farmers are slightly more cost-efficient overall |
| ROI (Profit / Total Cost)           | 1.12              | 0.98            | -0.14      | Untrained Farmers show higher return on investment         |

The findings show that yield of Trained Farmer is higher from Untrained Farmers which was 2,100 kg/ha as compared to 1,650 kg/ha i.e. The yield of Trained farmers

is 27 per cent superior than that of Untrained Farmers. This suggests that the extra instruction or technique practiced by Trained Farmers has a positive effect on productivity. But on the cost-effectiveness side, the picture is a bit muddier. Farmers (Untrained) Per unit of input under the following fixed inputs Fertilizer. PKR 27.27 less PKR 29.52 showing better use efficiency of nutrients used to generate per kg cotton product. On the other hand, it also shows that the Trained Farmers are financially sounder due to their low items purchase of pesticides (PKR 16.67 less then PKR 16.97) and apply imagined control treatment against insects. They also enjoy significantly lower profit per kg (PKR 45.24 versus PKR 49.70 on average), as inputs – for instance, fertilizer and other production expenditures – are more expensive. This is also observed in input cost per kilogram as it is comparatively high for Trained Farmers (PKR 46.19 vs PKR 44.24). Untrained Farmers have also a higher ROI (every rupee they invest generates 1.12 against only 0.98) that suggests they earn more money return per invested rupee concerning Trained Farmers. This implies that although yield-based strategies may achieve increased production, not always is a maximized profit assured without cost control.

## Discussion

The study also found that yield was significantly greater on farms owned by trained farmers than those run by untrained friends. In this respect, the average yield per hectare of trained farmers was 2100 kg; that for untrained farmers only 1650 The difference is almost 27 percent. And it's noteworthy—sharply contrasting with the training group arithmetically lower than its opposite-put training. Now, with the contrast less than 0.5 kg/ha and training group output higher as compared to none at all—we'll find that there are still significant differences in productivity between these two groups of people who have received different kinds or amounts (more than five sessions) formal instruction! The physicochemical characteristics of the water quality were also well within the stipulated by Zulfiqar et al. (2019) limits: their study showed BCI implementing farms in Pakistan more productive and environmentally-friendly as well. Parvathi et al. (2019) similarly reported that farmer training under BCI in Punjab used less water and fewer pesticides than open ones. Furthermore their yields were higher, suggesting again the importance of organized extension. In addition, the area per farmer was somewhat larger among

trained farmers—2.02 ha on average as against untrained 1.21 So it seems that while size doesn't matter for farm training (perhaps due to modern methods and practices), it may make all the difference when it comes to funds available for experimentation in such large applications as long an orchards bigger means better supplies. This implies certain fairness questions, too: unless institutions are financing it squarely, smallholder farmers will have no chance to get really involved in the program.

The other kind of efficiency is input efficiency and has a more complex relationship. Though both were able to attain better yield, cost of fertilizer per kilogram \((\text{kg})\) of cotton produced was found to be PKR 29.52 for trained farmer and higher as compared with illtrained farmer i.e. PKR 27.27. Similarly, total input cost per kg of cotton was slightly higher for the trained (PKR 46.19) as compare to untrained (PKR 44.24). This shows that along with the output increase input users get “extra” but not always proportional economic incentives due to input intensification. These results corroborated the reports of Ghori et al. (2022) observed that the BCI Pakistan and India farmers primarily increased input application to increase yields with mixed impacts on profitability. In contrast, Zulfiqar et al. (2019) found that fertiliser and pesticide usage for farmers having received training decreased which suggests that both the content and quality of the training matter, while farmer characteristics such as age may be likely to play an important factor if yield gains generated are to prove sustainable. According to Ali et al. (2024), pesticide usage decreases as farmers become aware of all possible and effective methods for controlling insect pests. Consequently, farmers' income and profits also increase.

Pesticide cost per kg cotton was slightly lower for trained growers (PKR 16.67) against PKR 16.97 for untrained, showing greater efficiency of pesticide use. This confirms the findings of Bonilla et al. (2018) also observed that the Plantwise clients could minimize pointless insecticide sprays and yields were not significantly different among non-trained and trained farmers. Although pesticide use was not a concern with this year's trials, as reported by Ashraf et al., the negative partial correlation between pesticides cost and yield ( $r = -0.25$ ) in the present study again emphasizes that overuse of pesticides remains an issue. (2024 when pest identification and appropriate handling are unknown, chemical controls can often be

rendered ineffective.

Profitability analysis revealed interesting contrasts. Although trained farmers achieved higher yields and overall profits per hectare (PKR 95,000 vs. PKR 82,000 for untrained farmers), the profit per kilogram of cotton was lower (PKR 45.24 vs. PKR 49.70). Moreover, the ROI for trained farmers (0.98) was below that of untrained farmers (1.12), indicating that trained farmers had lower efficiency in converting input investments into financial returns.

The cost-benefit ratios provide deeper insights: fertilizers generated the highest return (ROI = 2.8), followed by irrigation (ROI = 1.5), while pesticides yielded the lowest (ROI = 0.9). These findings are consistent with Tariq (2007), who argued that pesticide use in Pakistan often results in economic inefficiency due to indiscriminate application and resistance buildup. On the other hand, fertilizer consistently emerges as a profit-driving input in cotton systems when applied judiciously, which was also confirmed by Rehman et al. (2023), who showed that fertilizer use significantly enhances efficiency, provided it is balanced with other crop management practices.

There was a significant association between farmer education and crop rotation (chi square  $p < 0.0001$ ). Crop rotation was practiced by 15% of untrained farmers and 50% of the trained ones. This result suggests the influence of education in encouraging individuals to adopt an eco-friendly behavior. Crop rotation can keep soil in good health as well as reducing the risk for pests (and the use of expensive chemicals). Khan et al. (2022) Also observe that diversification and rotation of crops in farming at farm level are further intensified by the propagation of new things; this has in effect gone beyond simple economic compensation response (supported by the social as well as ecological effect). This latter finding is also in line with the training effect: If farmer are trained to grow their own cotton instead of relying on commercial crop land, yield increases. (Parathi, 2019). Consequently, intelligent Operation, scale, and output in economics. Positive regression results both of scale (farm size adjusted  $r = 0.11$ ,  $p < 0.01$ ) and Fallow land left fallow are independently significant elements for this productivity improvement scenario. All derived from our equation Pesticide application, on the other hand, has no correlation with the

result ( $r = -0.25$ ,  $p < 0.05$ ). This supports historical narratives that if a farmer takes to unrealistic or tentative use, productivity will go down rather than improving due. For example, analysis of variance results combined with interaction effects also show that fertilizer benefits are greater on the macro scale (Coef. = 0.12,  $p = 0.02$ ), while negative pesticide-controls interactions are significantly stronger in larger farms (Coef. =  $-0.08$ ,  $p = 0.04$ ). Therefore, this activity is scale dependent at input level. Larger farm sizes are more favorable for using fertilizer but less so for applying pesticides. This was a result in line with those of Hai et al. (2019), who found that larger farm hold more frequently use pesticides in an irresponsible manner in South Asia. The fact that at the latter times there was an increased application volume, poor supervision and storage capacity led to large numbers of generally toxic chemicals being in circulation means lower average environmental standards had to prevail. The society paid a heavy price for this lapse and even farmers themselves were very lucky if they got away without paying anything too serious toxic consequences.

## Conclusion

The trained cotton farmers were found to be more resource use efficient and economically better-off than their untrained counterparts in District Muzaffargarh. While being trained these farmers could adhere with the good production practices, make more efficient use of inputs (seeds, fertilizers, irrigation and pesticides), increased yields and ensuring a better profit. In contrast, the efficiency of untrained farmer was much lower; a high input wastage and low returns were also observed. The results indicate that farmer training and capacity building programs play a crucial role in maximizing cotton production, sustainable resource utilization and increasing farm level income in Southern Punjab.

## Recommendations

Based on findings it is recommended that farmer training and capacity building programs should be promoted to uplift increased and more diversified cotton grower community in South Punjab. Extension agents, welfare organizations and private sector partners should organize regular practical training on better use of inputs (including seeds), IPM measures, climate smart agriculture. It will be ideal if government policies could support such initiatives by including training modules in

the agricultural development plans and make funds available for them so that they can be sustained. Furthermore, the new extension methods such as mobile agricultural advisory services, demonstration plots and farmer field schools should be promoted for wider access to technical information. There also must be a method that the on-the-job training is effective and if not to improve. When the best practices of trained farmers are scaled up and success stories shared to attract untrained farmers into using improved practices, productivity can be boosted towards achieving cotton farming that is more profitable and sustainable.

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