Research Article

Adoption of Chip Bud Technology in Sugarcane Farming: Investigating Influential Factors in Central Khyber Pakhtunkhwa, Pakistan

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Abstract | The uses of chip bud technology in sugarcane cultivation increasing yield, uniform growth, requires reduced seed material and have high returns to the growers. The current study was undertaken to identify the factors influencing the adoption of sugarcane chip bud technology, examine the constraints faced by farmers in adopting chip bud technology. The primary data were collected from 52 sugarcane growers, comprising 31 adopters and 21 non-adopter of sugarcane chip bud technology, through a well-structured interview schedule. The logit model was used to determine the factors influencing the adoption of the chip bud technique in sugarcane cultivation. The findings revealed that the mean age of adopter farmers was 47.1 years, while for non-adopter farmers it was 46.71 years. Adopter farmers had an average of 19.45 years of sugarcane growing experience, compared to 15.95 years for non-adopter farmers who were involved full time in sugarcane farming. The mean schooling years for adopter was 9.32 years, while for non-adopter was 5.81 years. The results show that 45.2% adopter farmers and 34.6% of non-adopter farmers was owner of the land and practicing self-cultivation. Majority (96.8%) of adopter and 84.6% non-adopter had farm services centers membership. In addition, maximum (90.3%) of adopters and non-adopter (94.2%) do not have loan accessibility. Similarly, 80.6% adopter and 78.8% non-adopter has no facility of informal loan. The findings show that the mean landholding of the adopter farmers was 14.72 acres, likewise non adopter had 11.07 acres of land. Thus, (71%) of adopting and non adopting farmers had never attended training programs on sugarcane chip bud technology. The empirical results of the logistic regression model show that farm services centers membership and landholding are significant at the 95% confidence level, while education and sugarcane farming experience are significant at the 90% confidence level in influencing farmers' decision to adopt chip bud technology in sugarcane cultivation. The study suggested that the agricultural extension department to launch awareness campaigns, provide hands-on-training, establish demonstration plots, and ensure continuous monitoring through extension departments to address farmers' technical problems.

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Introduction

Agriculture sector is the driving force of Pakistan's economic growth. It contributes 23.5% to the country's Gross Domestic Product (GDP) and more than 37.7% to employment generation, ensuring food security and providing raw materials to the industrial sector (GoP, 2025). Additionally, it is a source of foreign exchange earnings and is crucial for sustainable growth. Sugarcane (*Saccharum officinarum L.*) is an important and the second-largest cash crop in Pakistan. Sugarcane contributes 3.5% to agricultural value addition and 0.8% to the overall Gross Domestic Product. The sugar industry is the second-largest agro-based industry, providing employment to millions of rural farming and non-farming communities and playing a vital role in the socio-economic development of the country (GoP, 2024).

Sugar consumption in Pakistan was 26.17 kg per capita, while total sweetener consumption, including sugar and jiggery was 27.92 kg per capita, which is higher than in other Asian countries such as India and Bangladesh. In Pakistan, sugarcane is primarily grown for sugar and jiggery production (PSMA, 2024). Sugarcane tops are major source of livestock fodder, especially during the winter season when fodder supplies shrink significantly (GoP, 2023).

Despite its significance sugarcane production in Pakistan faces persistent challenges. The country ranks 6th globally in both sugarcane area and production, yet its yield per hectare ranks only 25th (FAO, 2023). Similarly, Pakistan ranks 6th in sugar production and is 7th largest sugar consumer globally. According to PSMA (2024), sugar recovery in Pakistan during 2022-23 was only 10.22%, which is lower than in many other countries of the world. Similarly, sugar recovery in Khyber Pakhtunkhwa province was 10.53%, followed by at Sindh 10.39% and Punjab province at 10.12%.

In Pakistan, sugarcane yield is significantly lower than its potential due to poor management practices (Nazir *et al*., 2013). Yield gaps between potential and on-farm yields exist in many countries for several reasons. In the Asian region, the yield gap ranges from 17 to 50%, except in China, where it is 3.38% (Mondal, 2011). A significant disparity exists between improved practices and their adoption on farmers' fields, as reflected in poor yields (Tomar *et al*., 2012). The non-availability of disease-resistant varieties, inadequate plant protection measures, climate change, high production costs, and ineffective policies have laid pressure on sugarcane production (Raza and Amir, 2021). A substantial knowledge gap in recommended sugarcane production practices is a key reason for low yields (Farooq *et al*., 2019). Additionally, shortages of irrigation water, delayed payments by sugar mills, lack of technical knowledge, labor shortages, limited awareness, and unavailability of resistant varieties further contribute to the issue (Raza *et al*., 2020). The potential cane yield and sugar recovery can be enhanced if modern technologies are effectively transferred to farmers' fields.

However, the primary solution lies in enhancing productivity through the adoption of innovative technologies due to limited potential for expanding the area of sugarcane cultivation. Several technologies can help minimize cultivation costs in sugarcane farming. Chip bud planting, commonly referred to as the Sustainable Sugarcane Initiative (SSI) and integrate multiple viable technologies to boost productivity. The adoption of chip bud technology reduces seed rates, facilitates intercropping, lowers cultivation costs, and increases cane yield (Shanthy and Ramanjaneyulu, 2014).

Patnaik *et al*. (2017) reported that chip bud technology generated 32.63% higher net returns compared to conventional sugarcane cultivation. Khaliq *et al*. (2020) stated that chip bud planting is an advanced technique with greater potential to provide disease-free seeds and improve yields using a minimal quantity of seed compared to conventional methods. Nayak and Yadav (2021) noted that chip bud technology save costs and reduce the inconveniences associated with conventional planting methods, making them a highly promising and economically viable technique. Radha (2021) reported that the adoption of improved chip bud technology by sugarcane farmers could significantly increase their income. Galal and Yousif (2022) recommended the chip bud technique to achieve the highest cane and sugar yields. Samant (2017) found that the improved practice of the chip bud method resulted in a 39.7% higher cane yield compared to the farmer's conventional method. Zainuddin *et al*. (2019) stated that the chip bud method has the potential to be further developed through farming efficiency. By adopting these innovative techniques, sugarcane farmers can enhance their productivity and profitability, ensuring the sustainability of the sugarcane industry in Pakistan. Newton *et al*. (2021) reported that farm size is an important factor that farmers consider when making decisions about new technologies. Chauhan *et al*. (2021) found that the lack of adequate knowledge about these technologies among the indented beneficiaries limits adoption, highlighting the need for sufficient technical support to accelerate uptake.

To sustain the sugar demand for domestic consumption and export purpose, sugarcane was cultivated in Pakistan on an area of 1.1804 million hectares, compared to 1.3188 million hectares in the previous year, reflecting a 10.49 percent decrease in cane area. An inter-provincial comparison in Pakistan reveals that Punjab is the leading province in terms of sugarcane cultivation, with an area of 0.8001 million hectares, production of 63.3088 million tones and a yield of 79.1 tonnes per hectare followed by Sindh sugarcane area 0.2852 million hectares, production of 19.1354 million tones and a yield 67.1 tonnes per hectare and Khyber Pakhtunkhwa, with a sugarcane area 0.0944 million hectare, production of 5.1587 million tones and yield 54.6 tonnes per hectare. Notably, the cane yield per hectare in Khyber Pakhtunkhwa province is significantly lower compared to the other provinces. In Khyber Pakhtunkhwa, sugarcane is cultivated on 0.0944 million hectares, accounting for 7.99% of the total sugarcane area in the country (GoP, 2023). The top five sugarcane producing districts in Khyber Pakhtunkhwa were Mardan, Charsadda, Dera Ismail Khan, Malakand and Peshawar. These districts together cover about 93.02 percent of sugarcane area and 90.47 percent production of Khyber Pakhtunkhwa (Hassan and Farooq, 2024).

Recognizing the significance of chip bud technology, Sugar Crops Research Institute, Mardan of the Khyber Pakhtunkhwa province, has introduced and standardized this technology along with its associated production techniques. The agricultural extension department has been actively promoting sugarcane chip bud technology among sugarcane growers through various methods, including provision of chip bud machines to farmers, setting up demonstration plots and conducting field trails on farmers' fields, to increase and accelerate the adoption of this technology in the sugarcane growing areas of Khyber Pakhtunkhwa. The core objectives of this study are; to identify the factors influencing the adoption of chip bud technology in study area, to examine the constraints faced by the sugarcane farmers in adopting chip bud technology in the study area and to formulate suggestions based on the empirical findings of the study.

Materials and Methods

The present study is based on both primary and secondary data. Primary data were directly obtained from adopters and non-adopters of sugarcane chip bud technology in Mardan and Charsadda districts through a well-structured interview schedule designed by scientists at the PARC Social Sciences Research Institute, Tarnab, Peshawar, in consultation with scientists from the Sugar Crops Research Institute, Mardan. Secondary data were collected from various published and unpublished sources.

Location of the study and sampled selection

This study was conducted in the sugarcane growing districts of Mardan and Charsadda in Khyber Pakhtunkhwa. Sugarcane chip bud adopters in both districts were contacted through the agricultural extension department. A total of 31 sugarcane chip bud technology adopters, sixteen from district Mardan and fifteen from district Charsadda were purposively selected. To understand the perceptions of non adopter farmers regarding chip bud technology and to compare the perceptions of both adopter and non-adopters, 21 non adopter farmers, twelve from district Charsadda and nine (9) from district Mardan were randomly selected in the same areas where the adopters were interviewed. Overall, 52 sample farmers were selected, considering the nature of the study and resources constraints. Distribution of the sampled respondents is shown in Table 1.

Table 1: *Sampled distribution of adopters and non adopter farmers in the study area*

District	Adopter	Non adopter	Total
Charsadda	15	12	27
Mardan	16	9	25
Total	31	21	52

Source: *Survey data, 2024*

Data collection tools and techniques

Data collection began in January and February 2024, following the pre-testing of the interview schedule in the field. At the beginning of each interview, the aims and objectives of the study were explained to the respondents. Before visiting the field, adopter farmers were contacted and proper appointments were scheduled for the interviews. A total of 52 sampled farmers were interviewed. Data were collected using a well-structured and pre tested interview schedule at their farms, residences and Hujras (a drawing room where male guests are entertained in a household). During the survey, respondents were assured that the data collected would be used solely for research purposes and not for any other purpose.

Data analysis

The collected data were analyzed using SPSS (a Statistical Package for Social Sciences) to calculate averages, percentages and cross tabulation and logit regression model was also utilized.

Logit regression model

The logistic regression model is applied to predict the probability of binary events occurring based on predictor variables, assuming that individual decision maker makes rational choices to maximize their utility (Arthi *et al*., 2016). A logit model was applied to identify the factors that influence farmers' decisions to adopt either the chip bud technology or the conventional method in sugarcane farming. In this study, adopters of sugarcane chip bud technology are represented by '1', while non adopters are represented by '0'. Zainuddin *et al*. (2019) and Arthi *et al*. (2016) used a similar model. The logit model has been derived as follows:

$$Y(x) = \ln[y(x)/1-y(x)] = ß_o + ß_1X_1 + ß_2X_2 + ß_3X_3 + ß_4X_4 + ß_5X_5 + ß_6D_1 + ß_7D_2 + ß_8D_3 + ß_9D_4 + ß_{10}D_5$$

Whereas: Y= sugarcane chip bud technology adopter =1 and Non adopter =0

$ß_0$= constant $ß_1$, $ß_2$, $ß_3$, $ß_4$, $ß_5$, $ß_6$, $ß_7$, $ß_8$, $ß_9$, $ß_{10}$ are coefficient to be estimated

X_1 (age) = age of the respondents (in years)

X_2 (Education) = Respondents' years of education

X_3 (Experience) = Respondents' sugarcane growing farming experience (in years)

X_4 (family members) = Number of family members' involvement in sugarcane farming

X_5 (Landholding) = Landholding (in acres) of the respondents

D_1 (FSCs) = Respondents membership in farm services centers =1, Otherwise =0

D_2 (Tenancy Status) = If the respondent is the owner of the land =1, Otherwise =0

D_3 (Training) = If the respondent has received training =1, Otherwise =0

D_4 (Formal loans) = If the respondent obtained formal loans = 1, Otherwise =0

D_5 (Informal loans) = If the respondent obtained an informal loan =1, Otherwise =0

Results and Discussion

Socioeconomic profile of Sampled farmers

Table 2 presents the socio-economic characteristics of the sampled farmers. In the study area, the mean age of the adopter farmers was 47.71 years (ranging from 18 to75 years), while the mean age of non adopter farmers was 46.71 years (ranging from 25 to 70 years). The overall mean age of the sampled farmers was 47.31 years (ranging from 18 to 75 years). The results show that relatively middle aged members of farm families were operating sugarcane farming.

Farmers' experience plays an important role in their knowledge of recommended agricultural production technology (Hakim and Dipak, 2013). Data regarding sugarcane farming experience reveals that adopter farmers had 19.45 years of sugarcane growing experience (ranging from 4 to 50 years), while non adopter farmers had 15.95 years of sugarcane growing experience (ranging from 2 to 36 years). The results show that adopter farmers had more farming experience in sugarcane farming compared to non adopter farmers. In the study area, the mean sugarcane farming experience was 18.04 years (ranging from 2 to 50 years).

In the study area, on average, 1.87 family members were involved full-time in sugarcane farming. Adopter farmers reported that 1.71 family members involved full-time, while non-adopter farmers reported an average of 2.10 family members involved full-time in sugarcane farming. Ali *et al*. (2018) conducted a research study in the district D. I. Khan and found that the sampled respondents had an average age of 34.86 years, a mean farming experience of 11.17 years, and an average family size of 11.33 members per family.

The mean schooling years of the sampled adopter farmers was 9.32 years (ranging from 0 to 16 years schooling). Whereas, 23.8% of the non adopter farmers had up to 8 years of education and 19% each of the non adopter farmers had education between 9-10 schooling years and above 10 schooling years. The mean schooling years of the sampled non adopter farmers was 5.81 schooling years (ranging from 0 to14 schooling years). The literacy status of the overall sampled farmers indicates that one-fourth (25%) of the sampled farmers were illiterate, while the rest were educated to various levels in the study area. The overall mean schooling years were noted to

Table 2: *Socioeconomic characteristics of sampled farmers in the study area*

Farmers categories		Age (Years)	Farming Experience (Years)	Family members full time involvement in farming (#)	Education (Years)
Adopter	Mean	47.71	19.45	1.71	9.32
	Min.	18	4	0	0
	Max.	75	50	5	16
	Std. Dev.	14.20	14.51	1.24	5.04
Non-Adopter	Mean	46.71	15.95	2.10	5.81
	Min.	25	2	1	0
	Max.	70	36	4	14
	Std. Dev.	13.54	9.58	1.18	5.36
Overall	Mean	47.31	18.04	1.87	7.90
	Min.	18	2	0	0
	Max.	75	50	5	16
	Std. Dev.	13.81	12.76	1.22	5.41

Source: *Survey data, 2024*

Table 3: *Distribution of sampled farmers by tenancy status in the study area*

Tenancy status	Adopter		Non-Adopter		Overall	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Owners	14	45.2	4	19	18	34.6
Owner-cum-tenant	1	3.2	1	4.8	2	3.8
Tenants	7	22.6	8	38.1	15	28.8
Lessee	4	12.9	4	19	8	15.4
Owner-cum-Lessee	5	16.1	4	19	9	17.3
Overall	31	100	21	100	52	100

Source: *Survey data, 2024*

be 7.90 years in the study area (Table 2). Our results are contrary to Ali *et al*. (2018), who reported that the mean formal education of sugarcane growers in district D. I. Khan was 3.53 years.

Tenancy status

Tenancy is a written or verbal agreement between land owners (who lease out their land) and tenants (who take the land on lease) based on a mutually agreed division of the produce and crop production practices costs or an agreed land rent basis. In the study area, there were five categories of tenancy: owners, owner-cum-tenant (O-C-T), tenants, lessees and owner-cum-lessee (Table 3). It is noteworthy that 45.2% of adopter farmers were owners and self-cultivated their land, followed by tenants (22.6%), owner-cum-lessee (16.1%), lessee (12.9%), and owner-cum-tenant (3.3%). Additionally, 38.1% of non adopter farmers cultivated the land on a share basis, while 19% each of non adopter farmers cultivated the land of other farmers on a lease basis, were self-cultivators, and obtained land from other farmers on a lease basis.

The overall results indicated that 34.6% of sampled farmers were owners of the land and self-cultivated their land, while the remaining sampled farmers belonged to different categories of tenancy in the study area. Our results are almost similar to Khan *et al*. (2023) who noted that half (50.29%) of the sugarcane growers were tenants, 37.20% were owners who self-cultivated the land, and 12.5% were owner-cum-tenants in the districts of Mardan and Charsadda.

Membership in farm services centers

The Khyber Pakhtunkhwa government has introduced and launched farm services centers at the circle level, through which farmers' needs are identified. These centers provide quality inputs to member farmers at subsidize rates and also disseminate improved agricultural technology through various techniques at the doorstep of farmers. Table 4 presents the data on farm services centers membership. The results indicate that the vast majority (96.8%) of adopter farmers and 66.7% of non adopter farmers were connected with farm services centers and had formal membership, enjoying the facilities of these centers established at their circle level. In the study area, 33.3% of non adopter farmers and 3.2% of adopter farmers were not enrolled with farm services centers. The overall results show that the majority (84.6%) of the sampled farmers obtained formal farm services centers membership, and only (15.4%) of the sampled farmers were not linked with farm services centers in the study area.

Table 4: *Distribution of sampled farmers by farm services centers membership*

Membership	Adopter		Non-Adopter		Overall	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Yes	30	96.8	14	66.7	44	84.6
No	1	3.2	7	33.3	8	15.4
Overall	31	100	21	100	52	100

Source: *Survey data, 2024*

Loan obtained from formal and informal sources

Loans in agriculture are essential for financing inputs, equipment, and technology, enabling farmers to invest in and enhance productivity, resilience, and sustainable growth in the sector. Formal loans provide crucial financial resources to farmers, allowing them to invest in seeds, equipment, and technology for improved agricultural productivity. On the other hand, informal loans, often obtained from local lenders or market intermediaries (*Arthi*), offer flexible financing options tailored to farmers' needs, fostering resilience during economic uncertainty and crop failure. In the study area, the overwhelming majority (90.3%) of adopter farmers and all of non adopter farmers did not obtain loans for agricultural purposes from any formal sources. Only 9.7% of adopter farmers obtained loans from formal sources for agricultural purpose.

The Table 5 further reveals that the majority (80.6%) of adopter farmers and 76.2% of non adopter farmers did not obtain loans from informal sources, whereas 23.8% of non adopter farmers and 19.4% of adopter farmers received loans form informal sources. During discussions, the majority of the farmers reported receiving inputs on a credit basis from local input dealers; however, they did not obtain credit in monetary form from these input dealers in the study area.

Table 5: *Loan obtained by the sampled farmers from formal and informal sources*

Loan obtained	Adopter		Non-Adopter		Overall	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Formal Sources						
Yes	3	9.7	0	0	3	5.8
No	28	90.3	21	100	49	94.2
Overall	31	100	21	100	52	100
Informal sources						
No	25	80.6	16	76.2	41	78.8
Yes	6	19.4	5	23.8	11	21.2
Overall	31	100	21	100	52	100

Source: *Survey data, 2024*

Landholdings

The size of landholdings serves as a key determinant of the well-being of farming communities, significantly influencing their socio-economic status and political influence within society. It also affects farmers' decisions and reflects their ability to adopt improved recommended production practices and innovations in farming. The data regarding landholding is presented in Table 6. The findings show that the mean landholding of the adopter farmers was 14.72 acres (ranging from 1 to 75 acres), whereas non adopter farmers had 11.07 acres of land (ranging from 2.25 to 40 acres). Adopter farmers had more land compared to non adopter farmers in the study area. Table 5 further indicates that adopter farmers, on average, owned 13.93 acres of land, shared 11.08 acres, rented in 8.67 acres and shared out an average of 3 acres of land. The net operational landholding of adopter farmers was 14.52 acres.

The non adopter farmers had an average of 11.53 acres of own land, 8.42 acres of rented in land, 5.89 acres of shared land and 3.5 acres of shared out land. The non adopter farmers had an average of 10.90 acres of operational landholdings. The overall results show that, on average, the sampled farmers had 13.25 acres of landholdings (ranging from 1 to 75 acres), with their own land averaging 13.18 acres, shared in at 8.49 acres, rented in at 8.54 acres and shared out at 3.17 acres. The net operational landholding of the sampled farmers was recorded as 13.06 acres. The

Table 6: *Distribution of sampled farmers by landholdings (acres)*

Farmers categories		Overall land	Own land	Share in	Share out	Rented in	Operated land
Adopter	Mean	14.72	13.93	11.08	3	8.67	14.52
	Min.	1	1	2.5	1	1	1
	Max.	75	75	50	5	20	75
	Std. Dev.	17.46	19.70	14.90	2.83	8.25	17.16
Non-Adopter	Mean	11.07	11.53	5.89	3.5	8.42	10.90
	Min.	2.25	1	2.5	3.5	1.5	2.25
	Max.	40	40	11	3.5	32.25	40
	Std. Dev.	11.57	14.28	2.95	-	9.79	11.32
Overall	Mean	13.25	13.18	8.49	3.17	8.54	13.06
	Min.	1	1	2.5	1	1	1
	Max.	75	75	50	5	32.25	75
	Std. Dev.	15.33	17.97	10.76	2.02	8.78	15.06

Source: *Survey data, 2024*

average land lease was Rs. 79038 per acre per year in the study area. Memon *et al*. (2010) reported that sugarcane growers in central Khyber Pakhtunkhwa had an average of 12.80 acres of land, which is lower compared to farmers in Southern Sindh (74.45 acres) and central Punjab (27.48 acres).

Training program and sources

Table 7 reveals that the majority (71%) of adopting farmers and all non adopting farmers had not attended training programs on sugarcane chip bud technology, while 29% of adopting farmers reported receiving training on sugarcane chip bud technology. Overall, the data shows that the majority (82.3%) of sampled farmers had not attended training programs on sugarcane chip bud technology, while 17.3% stated that they participated in a training program organized by the agricultural extension department in the study area.

Table 7: *Training program received by the sampled farmers about chip bud technology*

Training	Adopter		Non-Adopter		Overall	
	Fre-quency	Per-cent	Fre-quency	Per-cent	Fre-quency	Per-cent
Yes	9	29	0	0	9	17.3
No	22	71	21	100	43	82.7
Overall	21	100	21	100	52	100
If yes source of training received						
Agricultural Extension	9	100	0	0	9	100

Source: *Survey data, 2024*

Logistic regression model

The logit model was used to determine the factors influencing the adoption of the chip bud technique in sugarcane cultivation. The dependent variables were categorized into two groups: adopter farmers using the chip bud technique, rated as 1, and non-adopter farmers using the conventional method, rated as 0. Based on a review of the literature and field conditions, ten independent variables were identified as potentially affecting farmers' decision to adopt either the chip bud technique or the conventional method. The ten independent variables include age (X_1), education (X_2), sugarcane growing experience (X_3), family members' involvement in farming (X_4), landholding (X_5), farm services centers membership (FSCs) (D_1), tenancy status (D_2), training (D_3), formal loans (D_4), and informal loans (D_5).

The results of the logistic regression model analysis shown in Table 8 indicate that landholding (X_5) and farm services centers membership (D_1) are significant at the 95% confidence level, while education (X_2) and sugarcane farming experience (X_3) are significant at the 90% confidence level in influencing farmers' decisions to adopt chip bud technology in sugarcane cultivation. The remaining variables do not have a significant effect. However, the variables education (X_2), sugarcane farming experience (X_3), farm services centers membership (D_1), tenancy status (D_2), training (D_3), formal loans (D_4) and informal loans (D_5) are positively associated with the adoption of chip bud technology. The higher these variables are, the greater

Table 8: *Empirical results of logistic regression model*

Variables	B	S.E.	Wald	Sig.	Exp (B)
X_1 (Age)	-.041	.039	1.063	.303	.960
X_2 (Education)	.202	.111	3.312	.069	1.224
X_3 (Sugarcane farming experience)	.082	.045	3.316	.069	1.086
X_4 (Family members involvement in sugarcane farming)	-.348	.395	.775	.379	.706
X_5 (Landholding)	-.121	.057	4.449	.035	.886
D_1 (FSCs)	3.369	1.619	4.329	.037	29.037
D_2 (Tenancy status)	1.414	1.126	1.576	.209	4.113
D_3 (Training)	24.364	9174.866	.000	.998	38113060814.2
D_4 (Formal loans)	25.269	17290.459	.000	.999	94224779397.7
D_5 (Informal Loans)	.776	.956	.660	.417	2.174
Constant	-2.820	2.035	1.920	.166	.060

Source: Survey data, 2024

the probability of adopting the chip bud technology. In contrast, age (X_1), family members' involvement in farming (X_4) and landholding (X_5) are negatively associated with the adoption of chip bud technology.

The level of education (X_2) of farmers has a significant effect at the 90% confidence level (α = 0.069) on their decision to adopt chip bud technology. The education level of farmers has a positive coefficient, indicating that the likelihood of adopting chip bud technology is positively associated with farmers' education. This means that higher levels of education increase the probability of adopting the chip bud technology. The odds ratio value for the education level variable is 1.224, indicating that with each additional year of education, the probability of farmers adopting chip bud technology increases by 1.224 times (ceteris paribus).

The significance of formal education in the adoption of sugarcane chip bud technology can be attributed to several factors. Educated farmers have greater access to information about chip bud technology through various media, such as print and electronic platforms. They are more exposed to new ideas, innovative practices and have greater opportunities to exchange knowledge with other farmers and agricultural departments.

The sugarcane farming experience (X_3) has a significant effect at the 90% confidence level (α = 0.069) on farmers' decisions to adopt chip bud technology. Sugarcane farming experience has a positive coefficient, indicating that the likelihood of adopting chip bud technology is positively associated with the farming experience in sugarcane farming. This means that the greater the farming experience of farmers, the higher the probability of adopting the chip bud technology.

The odds ratio value for the variable farming experience is 1.086, indicating that with each additional year of farming experience, the probability of adopting chip bud technology increases by 1.086 times (ceteris paribus). This significance may be attributed to several factors: over time, farmers develop greater expertise in sugarcane farming, engage more with the farming community, use resources more efficiently and enhance their ability to address challenges faced in farming. These factors collectively highlight the importance of farming experience.

The landholding (X_5) of farmers has a significant effect at the 95% confidence level (α = 0.035) on farmers' decisions to use chip bud technology. Landholding has a negative coefficient that the probability of a farmer using chip bud technology is negatively associated with the size of the landholding. Therefore, the greater the land area owned by farmers, the lower the likelihood of adopting sugarcane chip bud technology. The odds ratio value for the landholding variable is 0.886, meaning that an increase in land area by one acre will decrease the probability of farmers using chip bud technology by 0.886 times (ceteris paribus). This is attributed to the labor-intensive nature of cultivation using chip bud technology. The sugarcane chip bud technology requires higher labor costs and involves greater technical complexity compared to conventional methods. As a result, farmers are reluctant to allocate larger areas to this technology due to its complexity and feasibility issues on their farms.

The farm services centers membership (D1) has a significant effect at the 95% confidence level (α = 0.037) on farmers' decisions to use chip bud technology. Farm services centers membership has a positive coefficient, indicating that the likelihood of farmers using chip bud technology is positively associated with membership in farm services centers. Farmers who are members of farm services centers are more likely to use chip bud technology compared to those who are not members. The odds ratio value for farm services centers membership is 29.037, meaning that farmers with membership in farm services centers are 29.037 times more likely to use chip bud technology, ceteris paribus. This may be because members of farm services centers members are regularly in contact with these centers and develop relationships with agricultural extension workers. They also frequently visit the farm services centers to access improved and recommended agricultural production technologies, which they practically on their farms.

Our findings are closely aligned with Zainuddin *et al.* (2019), who reported that the education level and land area of farmers had a significant effect at the 85% confidence level (α = 15%) on farmers' decisions to use bud chip technology, while the age of farmers had no significant effect but exhibited a positive coefficient. Kiptot *et al.* (2007) found that age, education, farm size and the number of adults working on farms did not influence the adoption of fallows. Nyairo *et al.* (2021) reported that farm size had a significant level of 0.042 and a positive coefficient, indicating its effect on the adoption of improved technology. Sheikh *et al.*

Table 9: *Main constraints regarding sugarcane chip bud technology adoption*

Training	Adopter		Non-Adopter		Overall	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Labors work	5	16.1	2	9.5	7	13.5
Germination issues+ weak tillers	1	3.2	0	0	1	1.9
Scarcity of Irrigation water	4	12.9	2	9.5	6	11.5
inter cropping issues in direct chip bud method	1	3.2	0	0	1	1.9
Scarcity of irrigation water + Soil issues	1	3.2	0	0	1	1.9
Lack of knowledge + germination issues	1	3.2	0	0	1	1.9
Lack of land	0	0	1	4.8	1	1.9
Time Consuming method	1	3.2	2	9.5	3	5.8
Time consuming method+ more labors require	2	6.5	0	0	2	3.8
Poor results obtained	1	3.2	0	0	1	1.9
Lack of knowledge	8	25.8	6	28.5	14	26.9
Labors work+ termite issues	1	3.2	0	0	1	1.9
Soil issues	0	0	3	14.3	3	5.8
Small land on lease basis	0	0	1	4.8	1	1.9
Labors availability issues	1	3.2	0	0	1	1.9
High prices of inputs	1	3.2	0	0	1	1.9
Germination issues+ more labors require	1	3.2	0	0	1	1.9
More labors require + difficult technique	0	0	1	4.8	1	1.9
Lack of knowledge + more labors require	0	0	1	4.8	1	1.9
Chip bud field results not observed personally	0	0	1	4.8	1	1.9
Chip bud machine availability issues	1	3.2	0	0	1	1.9
Higher cost	0	0	1	4.8	1	1.9
Lack of land + higher risk	1	3.2	0	0	1	1.9`
Overall	31	100	21	100	52	100

Source: *Survey data, 2024*

(2003) observed that the number of extension visits had a significant effect with a negative coefficient, suggesting that farmers who received more visits were less inclined to adopt no-tillage practices. Extension, education and tenancy status were identified as the main factors influencing adoption. Arthi *et al*. (2016) reported that the education level of farmers' positive influenced their willingness to adopt chip bud technology, whereas household size, age and farm size showed negative coefficient.

Adoption constraints

There are many reasons for the low adoption of sugarcane chip bud technology in the study area, as shown in Table 9. The data indicate that 25.8% of adopter farmers reported a lack of knowledge as the main constraint preventing farmers from adopting sugarcane chip bud technology. Additionally, 16.1% of adopter farmers mentioned that raising sugarcane through chip bud technology required more labor compared to conventional methods, followed by scarcity of irrigation water (12.9%), the method being time consuming and requiring more labor (6.5%), germination issues combined with weak tillers (3.2%), intercropping challenges in the direct chip bud method (3.2%), scarcity of irrigation water combined with soil issues (3.2%), lack of knowledge combined with soil issues (3.2%), the method being time consuming (3.2%), poor results obtained (3.2%), labours work combined with termite issues (3.2%), labors availability issues (3.2%), high prices of inputs (3.2%), germination issues combined with more labors required (3.2%), chip bud machine availability issues (3.2%) and lack of land combined with higher risk compared to conventional method (3.2%).

Similarly, 28.5% of non adopter farmers reported that a lack of knowledge regarding sugarcane chip bud technology was the main constraints preventing them from adopting the technology. Additionally, 14.3% of non adopter farmers mentioned that the soil was not suitable for chip bud technology, followed by labours work (9.5%), scarcity of irrigation water (9.5%), lack of land (4.8%), the method being time consuming (9.5%), small land obtained on lease basis (4.8%), more labors required combined with difficult technique (4.8%), lack of knowledge combined with more labors required (4.8%), chip bud results not observed personally (4.8%), higher cost (4.8%).

The overall, results show that more than one-fourth (26.9%) of the sampled farmers stated that a lack of knowledge regarding chip bud technology was the main reason for not adoption the technology. Additionally, 13.5% mentioned labors work, and 11.5% cited scarcity of irrigation water as the main constraints. The rest of the sampled farmers reported various other problems they faced in the adoption of sugarcane chip bud technology, as indicated Table 9. Shanthy and Ramanjaneyulu, (2014) reported that the major constraints in the adoption of sugarcane chip bud technology were the non-availability of buds of the required sugarcane variety, scarcity of trained labor, and issues with timing for planting.

Conclusions and Recommendations

Based on the empirical results of the study, it is concluded that the sugarcane chip bud technology holds promise for improving yield; several challenges hinder its widespread adoption. Despite awareness and some adoption driven by agricultural extension efforts, significant barriers include lack of knowledge, increased labor demands and issues with soil suitability and irrigation. On the basis of empirical findings, the study suggested that:

The agricultural extension department should launch awareness campaigns using various communication channels to disseminate information and highlighting the long-term benefits of sugarcane chip bud technology, including higher yields and improve income to motivate sugarcane growers to adopt the technology. The agricultural extension department should establish more demonstration plots on farmers' fields, involving sugarcane growers from sowing to harvesting. This will allow farmers to practically learn the technology and showcase the benefits and proper techniques of chip bud technology, making it easier for farmers to adopt and practice on their farms in future.

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Novelty Statement

This study explores the untapped potential of chip bud technology in central Khyber Pakhtunkhwa, providing novel insights into the socio-economic and technological factors driving its adoption among sugarcane farmers.

Author's Contribution

Arshad Farooq: Designed the research study, data collection, data processing, analysis and write-up of the research article.
Abdul Hassan: Contributed in data collection, analysis and report writing.
Muhammad Ishaq: Supervised and design this research, helped during development of this research paper.
Asif Nawaz: Contributed in literature review, data analysis and write up.
Abdul Qadar: Contributed in results discussion.
Muhammad Usman: Contributed in format setting and write-up of the paper.

Generative AI or AI assisted technology statement
No AI technology has been used in this research article.

Conflict of interest
The authors have no conflict of interest.

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