Research Article

STAR CHANNA: A Climate-Resilient Innovation for Chickpea Cultivation in Punjab, Pakistan

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ABSTRACT

Star Channa, a newly introduced desi chickpea cultivar, is known for its high yield potential, large seed size, and built-in resistance to key chickpea diseases such as Fusarium wilt and *Ascochyta blight.* It received approval in 2021 from the Punjab Seed Council for widespread cultivation in irrigated and rain-fed areas of Punjab, Pakistan. The variety was evolved through artificial hybridization between female parent 98004 and male parent 5A015, utilizing bulk and pedigree methods of plant selection during various stages of breeding at the Arid Zone Research Institute in Bhakkar, Punjab, Pakistan. The selected line was tagged as TG1305 and then included in a series of yield assessments, pathological, entomological, and agronomic trials. Star Channa demonstrated a commendable average yield potential ranging from 3800 to 4000 kg/ha. It takes 88-90 days to reach 50% flowering and 138-145 days to reach 90% pod maturity. The seed size is bold, while seeds per pod ranged from 01 to 02. It has a 100-seed weight of 29-30 g, the number of pods per plant ranges from 75 to 80, the plant height is 65-68 cm, and the grain color is brown. As far as the quality is concerned, the protein percentage is high enough (23.9%) with desirable ash (3.63%) and crude fat contents (3.72%). It exhibited good yield potential when cultivated during October by maintaining a seed rate of 75 kg/ha and a fertilizer dose of 23-57-00 NPK kg/ha. In essence, Star Channa (TG1305) represents itself as a resilient and disease-resistant cultivar evolved to flourish in diverse environments and contribute to a sustainable farming system.

Keywords: Chickpea, Stress Tolerant, High-yielding, Food security, Poverty alleviation.

INTRODUCTION

Chickpea is considered a rich source of protein, essential amino acids, vitamins, minerals, and dietary fiber (Jukanti et al. 2012). Its strong capacity to fix atmospheric nitrogen through symbiotic microorganisms plays an important role in enhancing soil fertility (ABDOUN et al. 2022). Globally, chickpea is cultivated on nearly 15 million hectares, yielding about 15 million tonnes with an average productivity of 10,578 kg/ha. In contrast, Pakistan grows chickpea on approximately 0.8 million hectares and produces around 0.2 million tonnes with an average yield of 2650 kg/ha (FAO, 2021). This makes Pakistan the seventh-largest chickpea-producing country, contributing roughly 2.5% to global output (Rasool et al. 2023).

Chickpea stands out as the most significant crop which occupies 73% of the total pulse-growing area and contributes to 76% of the total production. It is followed by mungbean, which occupies 18% of the total cultivated area, and blackgram, which covers for 5% of the total area (Shrestha and Neupane 2016). The protein contents in pulse grains range from 15 to 30% (Hall et al. 2017). Especially, chickpea have a protein content ranging from 17% to 19%(Cai et al. 2002, Sreerama et al. 2012). Pulse production in Pakistan is 0.7 million ton while the total consumption is about 1.5 million tone. To fulfill the requirements, Pakistan

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has to import 0.8 million ton pulses every year (chickpea, lentil, mungbean and mashbean) mostly from Australia, Canada, USA, China, Russia, Ukraine and Africa. In the light of challenges posed by climate change, food insecurity and water shortage, enhancing the production of cereals, pulses, fruits, and vegetables is essential to meet the dietary needs of Pakistan's growing population. In Pakistan, most of the people living in rural areas consume considerable quantity of pluses as their daily meal needs because these are rich source of protein and alternate of other expensive sources of protein e.g. meat and fish. Chickpea and lentil are grown as minor crops and the worldwide area under cereals is about ten times greater than that of these pulses (Cernay et al. 2016). The average consumption of pulses in the world is 7 kg/person/year (https://www.fao. org/pulses-2016). One of the key challenges faced by crop breeders is the critical need to enhance crop yields in order to sustainably feed the estimated global population of 10 billion by 2050.(Hickey et al. 2019). Breeding techniques have indeed produced superior crop varieties, yet the continued reliance on these methods has failed to meet the both yield and nutritional requirements(Roorkiwal et al. 2020).The irrigated area of chickpea is scattered throughout the Punjab and it is consistently decreasing due to non-availability of high yielding varieties that can compete to the cereals. Moreover, both biotic and abiotic stresses severely affect the chickpea crop and its production. Biotic stresses comprise various diseases such as Ascochyta blight (*Ascochyta rabiei*), Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris*), Botrytis grey mould, root rot, and stunt, among others. Additionally, major insect pests include pod borer (*Helicoverpa armigera*), black cutworm, aphids, leaf miners, and bruchids. Similarly, heat, drought, salinity, frost and chilling are the abiotic stresses affecting chickpea productivity(Jha et al. 2014, Maphosa et al. 2020).Biotic stresses can be strategically managed by developing effective breeding technologies, including novel, conventional, and molecular approaches (Manjunatha et al. 2022). Utilizing resistant varieties remains the most cost-effective and optimal approach for management of pod borer infestations (Patil et al. 2017).Over the past five years, the chickpea cultivation area in the country has remained relatively constant, experiencing minor fluctuations. However, the production profile has shown significant fluctuations, indicating instability. Chickpea cultivation primarily occurs in areas designated for dry land agriculture, making it highly susceptible to changes in natural environmental conditions. Expanding the cultivation area for chickpea horizontally could be accomplished by developing high-yielding varieties suitable for those specific regions.

Climate change poses a major threat to agriculture. Innovations targeting on climate-smart farming practices and resilient crop varieties aid in mitigating the adverse effects of climate change, safeguarding food security. In light of the current situation, it is essential to focus on the development of chickpea varieties that are capable of responding to high inputs, such as fertilizers and water, while also demonstrating resilience to various environmental stresses, both abiotic (such as drought, salinity, and temperature fluctuations) and biotic (such as pests and diseases). By prioritizing the breeding and cultivation of such resilient varieties, we can ensure more stable chickpea production even in challenging environments. Chickpea cultivation is aligned with the vision for 2063 by aiming to adapt to climate change, as the crop exhibits resilience across various cropping systems (Phiri et al. 2023). Major opportunities for augmenting pulses production include development of high yielding, insect pest, disease resistant and climate smart varieties, strengthening of certified seed distribution system, development and dissemination of site-specific production technologies and seed improvements are also essential (Ullah et al. 2020).Conventional breeding methodologies have made a remarkable enhancement in chickpea and contributed towards bringing pulses independency in India. In response to the challenges faced in chickpea production, significant efforts were started to develop varieties that address key issues such as low yield, susceptibility to wilt and blight, and adaptability to changing climates. At the front line of these activities is the Arid Zone Research Institute Bhakkar, which exploits genetic diversity present in chickpea germplasm. Due to the abundant genetic variability available, the institute has undertaken continuous research efforts. This led to the release of various chickpea varieties for general cultivation. These varieties consist of Thal-2006 and Bhakkar-2011, as acknowledged by the authors (Muhammad Arshad et al. 2008, Aslam et al. 2013), alongside Thal-2020 and TG Striker. Each of these varieties is tactfully developed to demonstrate characteristics such as high yield potential and resistance to widespread diseases such as wilt and blight. The results of the research showed that the newly developed line outperformed the commercial control varieties in most traits like resistance against diseases, insect pest and yield (Ercan et al. 2013).

In short, the evolution and introduction of new chickpea cultivars is an important step to address the tasks in chickpea cultivation. These efforts don't just promise to increase productivity and profitability but also contribute to improving food security and reducing import bill and thereby promoting the sustainability and resilience of agriculture sector.

MATERIALS AND METHODS

General Experimental Details

Two and a half bag of DAP fertilizer per hectare was incorporated into the soil at the time of land preparation. Sowing was completed in the month of October. All agronomic practices, including weeding/hoeing, irrigation, and insect pest control, remained consistent across all experimental genotypes. The experimental design was a randomized complete block (RCB) with three replications for all yield, entomological and pathological trials. Standard row-to-row and plant-to-plant distances of 30cm and 15cm were maintained accordingly. In all trials, two seeds were initially placed per hole to ensure optimal plant population per plot, followed by thinning to one vigorous seedling after 20-25 days of germination. The plot size was kept consistent at 4×1.2 m² for all station (preliminary, advanced/regular) and adaptation (micro, provincial) yield trials. For national uniform yield trials (NUYTs), the plot size was maintained at 4×1.8 m². Each trial included at least one to two checks to evaluate the performance of the test entries.

Evolutionary Journey

The evolutionary journey of chickpea advance line TG1305 spans from 2005 to 2021 (Table 1), characterized by meticulous breeding efforts and comprehensive trials aimed at developing a vigorous and high-performing cultivar. In 2005-06, the hybridization program was initiated by crossing the female parent 98004 with the male parent 5A015 to creating new genetic combinations. This artificial hybridization process was carried out according to the methodology provided by the author (Kalve and Tadege 2017) and several recent chickpea cultivars were evolved through technique (Gaur et al. 2012). The fundamental steps of a breeding program involve generating genetic variability, selecting desired genotypes based on their desirable traits, and then evaluating the selected lines for their performance and characteristics (Raina et al. 2019).F_0 generation seeds were harvested and collected from successful crosses for further evaluation in successive generations (F_1 to F_5) subjected to rigorous single plant selection processes to identify and retain desirable traits. Further enhancement of genetic purity and stability was pursued through selections in the F_6 and F_7 generations. Normally, breeding programs use a cycle of selection, recombination, and further selection to evolve new varieties.

This procedure typically requires five to six successive generations to attain genetic homozygosity, after which the varieties are evaluated for their performance and stability (Roorkiwal et al. 2020). Bulk and pedigree methods of plant selections were carried out during the various breeding-stages. Uniform and true to type pure lines were selected because it achieved maximum homozygosity by the F_7 generation and bulked. The selected line was identified as TG1305 and then included in a series of yield assessment trials. Yield trials were initiated in 2013-14, progressing from preliminary to regular and micro trials, evaluating yield potential and adaptability under various conditions. Extensive agronomic, pathological, and entomological studies were conducted from 2017-18 to 2018-19 to provide insights into optimal cultivation practices and resistance to pests and diseases. The advance line underwent provincial and national yield trials, affirming its performance across diverse regions from 2018-19 to 2019-2020. In 2020-21, seed multiplication was initiated to ensure an adequate supply of high-quality seeds. Throughout this evolutionary process, the focus remained on selecting for traits like yield potential, disease resistance, and adaptability, with the overarching goal of developing a superior chickpea cultivar ready for widespread adoption by farmers.

Table 1. Evolutionary History of chickpea strain TG1305

Year	Generation/ Trial	Operation
2005-06	Hybridization Program	Crosses (98004 female x 5A015 male) attempted and F0 seed harvested
2006-07	F_1	Seed of F1 harvested
2007-08	F_2	Single plant selection
2008-09	F_3	Single plant selection
2009-10	F_4	Single plant selection
2010-11	F_5	Single plant selection
2011-12	F_6	Selection of pure and uniform lines
2012-13	F_7	Selection of pure and uniform lines
2013-14	Preliminary Yield Trial	Yield data were recorded
2014-15	Regular Yield Trial	-do-
2015-16	Micro Yield Trial	-do-
2017-18	Provincial Yield Trial	-do-

2018-19 to 2019-20	National Uniform Yield Trial	-do-
2017-18 to 2018-19	Agronomic, pathological and entomological Studies	Different level of sowing date, seed, fertilizer, planting geometry, irrigation level, disease and insect pest infestation were recorded.
2020-21	Seed multiplication	BNS was produced.

Pathological and Entomological Studies

In order to determine the specific disease response of the candidate variety (TG1305), separate pathological experiments were conducted, distinct from the regular breeding experiments. These experiments were conducted in collaboration with the pathological and Entomological section of this institute. Furthermore, the strain was subjected to tests for tolerance against insect pests, specifically pod borers, in replicated yield trials, alongside the Bittle-2016 as check variety.

Genetic Polymorphism Analysis Using SSR Markers

Experimental Material

Fully mature, uniform size and viable seeds of chickpea genotype TG1305 were raised in plastic pots and post germination; 14 days old seedlings were used for the collection of young leaves. The leaves were immediately stored at -80℃.

Genomic DNA Isolation and Quantification

Fresh and fully expanded chickpea leaves weighing about 250g were used for DNA extraction by employing modified cetyltrimethylammonium bromide (CTAB) method. The quality of genomic DNA was assessed by running 10 ng sample on 1.0% agarose gel prepared with 0.5X TBE buffer having (0.5µg/ml) ethidium bromide as staining agent. Extent of concentration and purity of DNA sample was determined by using a spectrophotometer (Nano Drop® ND-2000) at absorbance of OD-230/260/280. Intact and highly pure genomic DNA was stored at -20 °C for further analysis.

Simple Sequence Repeat (SSR) Markers for Study

SSR primer pairs were sourced from chickpea reference database (Ahmad et al. 2014, Agarwal et al. 2015). Out of these reported microsatellite markers, 54 highly polymorphic markers having wide genome coverage and multiple amplification bands among the standard check cultivars 'Thal-2020', Rohi Channa-20', Bhakkar-2011' of chickpea and candidate variety 'TG1305' were selected for varietal identification via qualitative PCR analysis (Table 2).

Table 2. List of SSR Markers and Forward Reverse Sequences

S. No	Primer Name	Forward Primer	Reverse Primer
1	ICCM0249	TTTCTTCGCATGGGCTTAAC	GGAGATTTGTTGGGTAGGCTC
2	CaGM00495	CCACCACATTTCATCACTCG	TTAGGGTCTCCGTCGTATGG
3	CaGM00515	ATCGATTTGGGGGAAATAGG	AGACAAAGCCATAACCGTGG
4	ICCeM0050	GCGAATCAATGTTCACAAGC	GAGGGAACACCAACTCCAAA
5	CAM1577	TCCTTTGTTTTTCCTTTCTTCCT	AATGCGTTACGGGTGAAATG
6	NCPGR223	TGGGTTTCTTTTCTTGAAGC	AGTGGGTTGAGAAATTACGG
7	NCPGR138	ATTCCAAATTGCTGTTGTTTG	TGTGGATTTTAGTTGCAATG
8	ICCM0105	TGCTTCCTTTTCAATCACCA	TGACAAAGGACAAATAAGTGTTTTA
9	CCM0228	TGGACGTAGGTTGTTGTGGA	GGACCGGGAGTCCCTTATTA
10	ICCM0301	ATGGCCAAAATGAACTCCAG	AAAGAGAAGGTTCCATCGG
11	CaSTMS2	ATTTTACTTTACTACTTTTTTCCTTTC	AATAAATGGAGTGTAAATTTCATGTA
12	CaSTMS15	CTTGTGAATTCATATTTACTTATAGAT	ATCCGTAATTTAAGGTAGGTTAAAATA
13	CaSTMS21	CTACAGTCTTTTGTTCTTCTAGCTT	ATATTTTTTAAGAGGCTTTTGGTAG
14	TA72	GAAAGATTTAAAAGATTTTCCACGTTA	TTAGAAGCATATTGTTGGGATAAGAGT

15	TA130	GAAAGATTTAAAAGATTTTCCAC GTTA	TTAGAAGCATATTGTTGGGATAAG AGT
16	TA194	TTTTTGGCTTATTAGACTGACTT	TTGCCATAAAATACAAAATCC
17	TA71	CGATTTAACACAAAACACAAA	CCTATCCATTGTCATCTCGT
18	TA22	TCTCCAACCCTTTAGATTGA	TCGTGTTTACTGAATGTGGA
19	TA200	TTTCTCCTCTACTATTATGATCAC CAG	TTGAGAGGGTTAGAACTCATTATGT TT
20	TA46	TTTATTGCAATAAAACTCATTTCT TATC	TTCTTTTTGTGTGAAAAAAAAATAT AGTA
21	TR1	CGTATGATTTTGCCGTCTAT	ACCTCAAGTTCTCCGAAGT
22	TR29	GCCCACTGAAAAATAAAAAG	ATTTGAACCTCAAGTTCTCG
23	TR31	CTTAATCGCACATTTACTCTAAA ATCA	ATCCATTAAAACACGGTTACCTATA A
24	CakTSSR001 18	GTTCACCACAGAATTCATCAT	ACGATTTCCGATTCATCTTA
25	CakTSSR003 92	CTTGCAAGTAAAAGTGTTTGG	ATTTGGAAGGTTTATGGAGAA
26	CakTSSR006 21	TTCTCTCTCGTCTCTGGAGTT	TCCCTCGCAACTAATATAACC
27	CakTSSR007 29	TCGTAGACACGAAAATCTGTT	AACCTTGATCAACATCTGGTA
28	CakTSSR007 63	TGCAACAGGGTTTAACTCTAA	ACATAAGCACTC0CACATGAAC
29	CakTSSR013 94	GTTGGATTGAAGATTTCGAG	TGCAACAACACTATTGAAGAA
30	CakTSSR026 55	TTGTCAGAAGTTGATGGTTCT	GAATCAAAATCTAGCAGCTCA
31	CakTSSR026 67	CTATGACAAAGTGGCATGATT	ATCCACTTATCATTTGACGTG
32	CakTSSR030 39	ATGATATTGAAGGTGGTGATG	ATTAGGACACCTTTGAAATCC
33	CakTSSR030 99	GTTTGCGCTAAACAATATTAGA	GTTTGCAGTGAAAAGAACAGT
34	CakTSSR031 18	AATCCATGTCTTAATCTGCAA	GAATTTGAAGAGCCCTAAGAG
35	CakTSSR032 48	CTAAAGAATGGAATTGGGATT	CTCGTTTGTTTGCTCTATTGT
36	CakTSSR033 32	ACCCAACTTTGTACCTACCAT	TAGAAACTTGTGGTGGAGATG
37	CakTSSR038 99	TTACACTATATGCGGTATCTGC	ATCAAACTCAGTAGGCCAAA
38	CakTSSR039 70	TGAGGTTGAGAATTTGAGTGT	CTCACTTCTCATCACCATCAT
39	CakTSSR040 52	GCGTGAAGAAGAGAGAGAGAT	TTGTTAGGCCTTAATCAATCA
40	CakTSSR040 62	CTCAAATATCTCTCCCAACCT	GTCGTCGGAGAAATAGTCTTC
41	CakTSSR042 14	TAAAAGATGCTGCAAGAAGTG	AAAGAGACAATGAAAGGGGTA
42	CakTSSR042 55	CTCATTCCATTATCCCCTTAC	TGAGGATAGTGTTGAGAGGTG
43	CESSRDB4	GAAGAGGTAGCGGAGGAG	CAAGCAACAGTTTTCACTCA
44	CESSRDB5	CCGACATCTCTTCTCAATTC	CTTTAGGTGGTGGTTGTTGT

45	CESSRDB7	AAGTGGTGTCGGTAATGGT	TAATACCAAAAGCATGCACA
46	CESSRDB11	AATCTAACAGCAACGACGAT	ATCAAGCTTCTTCTGCACAT
47	CESSRDB13	ATCTGGGAGCTTGTGAGTTA	TTGTATCTCCTTCAGATGGC
48	CESSRDB15	CTTACGATTTCTCCTCCCTT	TTTCTCATACCGAATCCTTG
49	CESSRDB16	ATGCTATGCATGATGTTTCA	GTTCCAAACAAACACAACAA
50	CESSRDB21	GTGTATCGGTCAGGAAAAGA	GGTACACACCACAATTCACA
51	CESSRDB23	GTGTGGACCTGAAATTGAGT	GAATATGGGAACAAGTGCAT
52	CESSRDB24	TGTGCTTGACTTGTTCACAT	TATGCATCCTCATTTTCTCC
53	CESSRDB27	GGTGAGATTAGGAAGCAATG	TATCCAATCCCCATAAGATG
54	CESSRDB29	TTTAGTTGCACAACAACAGC	AAATCCACATCCAAAAAGGT

PCR Amplification and Amplicon Analysis

PCR amplification analysis was performed on 200 DNA samples of 4 chickpea genotypes by using 54 SSR markers. Twenty microliter reaction mixture containing 10ul of Green master mix (Thermo Scientific, USA), 10uM of forward and reverse primers and 100ng of genomic DNA as template. Thermal cycler (SC300G-R2, Kyratec, Australia) profile was set for Initial denaturation at 95℃ for 5 min followed by 30 cycles of denaturation at 95℃ for 30sec, annealing temperature ranged between 55-57℃ for 30 Sec, and extension temperature was set at 72℃ for 1 min followed by a final extension step of 72℃ for 5 min.

Polyacrylamide Gel Electrophoresis (PAGE)

To analyze polymorphism, 4 µl of the PCR-amplified product was separated on a 6% polyacrylamide gel prepared with a 19:1 acrylamide to bis-acrylamide ratio. A 50 bp DNA ladder (Fermentas, USA) served as the molecular marker to estimate allele sizes. The resulting bands were visualized using silver nitrate staining following standard procedures. The polyacrylamide gel was then photographed under fluorescent illumination, and the image was digitally captured with a gel documentation system (EZEE Gel Pro, Cleaver Scientific, USA).

Band Recording and DATA Analysis

The binary data matrices attained from PAGE of SSR markers was recorded in Microsoft excel format. The presence of band was scored as '1', while the absence was scored as '0'. The resulting binary data matrix was used for constructing dendrogram. Cluster analysis was performed on the similarity-coefficient-matrix. The Jaccard similarity matrix was used for cluster analysis using Unweighted-Pair-Group-Method-of-Arithmetic (UPGMA) (Jaccard 1908) into Numerical Taxonomy System of Multivariate Programs called NTSYS-pc, version 2.20N(FJ 2000). Exact size of DNA fragment was recorded for each genotype under separate primer pair. The discrete bands were identified and considered as DNA finger prints.

Quality Test

The experiments on the physio-chemical properties of candidate variety TG1305 grains were carried out at the Agricultural Biochemistry Laboratory of the Ayub Agricultural Research Institute, Faisalabad. The crude protein content, ash percentage, and crude fat percentage of the candidate line TG1305 were measured and compared with those of a commercial check variety Bittle-2016. The yield means were subjected to statistical analysis using Statistics 8.1 software, as described by the author (Steel et al. (1997).

Agronomic Studies

These studies involve a comprehensive examination of various factors that influence its growth, development, and productivity. These studies covered various research areas with the goal of optimizing agronomic practices for new strain TG1305 to achieve maximum production. For two consecutive years, from 2017-18 to 2018-19, trials were carried out to assess the best planting time, seed rate, planting arrangement, and nutrient management for the new advance line TG1305. Local commercial varieties were included in these trials to comparison of yield.

RESULTS AND DISCUSSION

Station Yield Trials

In the Preliminary Yield Trial conducted at AZRI Bhakkar during 2013-14, the candidate variety TG1305 demonstrated significantly higher yield (2050 kg/ha)as compared to check varieties Punjab-2008 (1622kg/ha) and Bhakkar-2011 (1664kg/ha), reflecting percentage increase of 26% and 23%, respectively as shown in table 3.Similarly, in the Regular Yield Trial conducted in the following year (2014-15), TG1305 maintained its superior performance with a yield of 1150kg/ha , showing percentage increases of 15% and 51% over the check varieties Punjab-2008 (999kg/ha) and Bhakkar-2011 (764kg/ha), respectively. Overall, in both the preliminary and regular yield trials conducted at AZRI Bhakkar, TG1305 consistently outperformed the check varieties Punjab-2008 and Bhakkar-2011.These results suggest the potential of TG1305 as a promising chickpea variety, particularly in the Bhakkar region. In the Micro Yield Trial conducted at AZRI Bhakkar, TG1305 showed significantly higher yields (1105 kg/ha) compared to the check varieties from both Punjab-2008 (606 kg/ha) and Bhakkar-2011 (1018 kg/ha). TG1305 yielded 82% higher than the check from Punjab-2008, and 9.0% higher than the check from Bhakkar-2011. Similarly, in the Micro Yield Trial conducted at GBRSS, Kallur Kot, TG1305 demonstrated higher yields (1316 kg/ha) compared to the check varieties from both Punjab-2008 (1000 kg/ha) and Bhakkar-2011 (1256 kg/ha). TG1305 yielded 32% higher than the check from Punjab-2008, and 5.0% higher than the check from Bhakkar-2011. Based on the comprehensive data provided, TG1305 exhibits promising performance across various trials including preliminary, regular and the micro yield trials conducted at AZRI Bhakkar and GBRSS, Kallur Kot. Its higher yields compared to the check varieties highlights its potential as a promising option for chickpea cultivation in similar agro-climatic conditions.

Table 3. Performance of TG1305 as "Star Channa" in Station Yield Trials

Year	Name of Trial /Location		Yield ($kgha^{-1}$)			+/- Over check (%)
			Checks		TG1305	
2013-14	Preliminary Yield Trial (PYT)-AZRI Bhakkar		Punjab-2008	1622	2050	26 23
			Bhakkar-2011	1664		23
2014-15	Regular Yield Trial (RYT)- AZRI Bhakkar		Punjab-2008	999	1150	15
			Bhakkar-2011	764		51
2015-16	Micro Yield Trial (MYT)	AZRI Bhakkar	Punjab-2008	606	1105	82
			Bhakkar-2011	1018		9.0
		GBRSS, Kallur Kot	Punjab-2008	1000	1316	32
			Bhakkar-2011	1256		5.0

Provincial Yield Trial

Table 4 presents yield data for three different chickpea varieties / strains: TG1305, Bittle-2016 (check), and Punjab-2008 (check), across various locations in Punjab during the 2017-18 growing season. These locations include research stations and farmers field. For TG1305, the yields ranged from 615 kg/ha to 3219 kg/ha across different sites. The highest yield for TG1305 was recorded at PRI AARI Faisalabad, with 3219 kg/ha, followed by 2129 kg/ha at NIAB Faisalabad. The lowest yield for TG1305 was observed at GBRSS Kallur Kot with 615 kg/ha. The average yield for TG1305 across all sites was 1807 kg/ha. For Bittle-2016 (check), the yields varied between 358 kg/ha and 3704 kg/ha. The highest yield for Bittle-2016 was observed at PRI AARI Faisalabad, with 3704 kg/ha, while the lowest yield was recorded at GBRSS Kallur Kot with 358 kg/ha. The average yield for Bittle-2016 across all sites was 1763 kg/ha. For Punjab-2008 (check), the yields ranged from 451 kg/ha to 3424 kg/ha. The highest yield for Punjab-2008 was observed at PRI AARI Faisalabad, with 3424 kg/ha, while the lowest yield was recorded at Mankera Farmer Field with 451 kg/ha. The average yield for Punjab-2008 across all sites was 1741 kg/ha. Comparing the three varieties / strains, TG1305 generally exhibited competitive or higher yields compared to Bittle-2016 and Punjab-2008 across most locations. The increase over checks percentage indicates that TG1305 yielded 4.0 % higher on average compared to Bittle-2016 and 2.50 % increase over check Punjab-2008. These yield data deliver valuable understandings into the performance of different chickpea varieties under different growing conditions in Punjab and supports in selecting suitable varieties for cultivation.

Table 4. Performance of TG1305 as "Star Channa" in Provincial Yield Trial

Year	Site/ locations	TG1305	Bittle-2016	Punjab 2008
2017-18	PRI AARI Faisalabad	3219	3704	3424
	NIAB, Faisalabad	2129	1591	1725
	GBRSS Kallur Kot (Irrigated)	1132	1028	1142
	AZRI Bhakkar (Irrigated)	3080	2486	2684
	ARS Karor (Layyah)	2486	2802	2680
	RARI Bahawalpur	2083	2292	2222

	GBRSS Kallur Kot (Rainfed)	615	358	472
	AZRI Bhakkar (Rainfed)	392	1028	867
	Mankera Fermer Field	1126	576	451
	Average Yield (kgha^{-1})	1807	**1763**	**1741**
	+/- Increase over checks (%)		**4.0**	**2.50**

National Uniform Yield Trials

Yield data of the chickpea advance line TG1305 compared to the control varieties (Bittle-2016 and Indus-2019) at diverse locations for the two years is shown in Table-5. During 2018-19, the yield data of chickpea advance line TG1305 showed different performance results at different locations in Pakistan. At PRI, AARI Faisalabad, TG1305 yielded 1613 kg/ha, slightly lower than the control variety Bittle-2016 which yielded 1892 kg/ha. In contrast, for ARS Karak, the yield difference between TG1305 (1229 kg/ha) and the control variety (1233 kg/ha) was insignificant. Notably, at AZRI Bhakkar, TG1305 outperformed the control variety and gave a yield of 2400 kg/ha as compared to 2125 kg/ha. Likewise, TG1305 showed higher yield (1290 kg/ha) than the control variety (1193 kg/ha) at AZRI Bahawalpur. At AZRC D.I. Khan and BARI Chakwal, the yield of TG1305 was slightly lower than that of the controls. A notable rise in yield was observed in TG1305 giving a yield of 1736 kg/ha compared to the control (Bittle-2016) which gave a yield of 1431 kg/ha at GBRSS Kallur Kot. The biggest difference was observed at NARC Islamabad, where TG1305 delivered a yield of 3245 kg/ha, significantly exceeding the control variety (2288 kg/ha). On the contrary, the yield of TG1305 (1388 kg/ha) was slightly lower than the control yield (1417 kg/ha) at NIAB Faisalabad. However, TG1305 showed higher yields compared to the test at NIFA Peshawar and QAARI Larkana. Generally, TG1305 showed encouraging performance with an average yield of 1732 kg/ha, demonstrating a 9% higher yield over the control variety Bittle-2016, although with variations between different locations. During 2019-20, TG1305 showed different yields compared to the control variety Indus-2019 at different locations. At PRI, AARI Faisalabad, TG1305 yielded 592 kg/ha, which is significantly higher than the control variety's yield of 319 kg/ha. Similarly, at ARS Karak, TG1305 yielded 643 kg/ha, considerably lower than the control yield of 1077 kg/ha. However, in AZRI Bhakkar, TG1305 showed higher yield of 1217 kg/ha as compared to control variety yield of 1077 kg/ha. However, TG1305 gave a yield of 1632 kg/ha against standard check (1875 kg/ha) at AZRI Bahawalpur. Elsewhere the performance was varied; For example, at BARI Chakwal, TG1305 gave a yield of 593 kg/ha, slightly less than the control variety's yield of 535 kg/ha. However, in GBRSS Kallur Kot, TG1305 showed significantly higher yield of 2403 kg/ha as compared to 1681 kg/ha in control. In 2019-20, the average yield of TG1305 was 1397 kg/ha, while the control variety had an average yield of 1308 kg/ha. This indicates an average yield increase of 7% for TG1305 over the control variety Indus-2019. The yield performance of TG1305 varied from site to site, showing its resilience and potential for improved chickpea production under different agricultural environmental conditions. Similarly, Bittle-2022 was evolved through testing in a series of trials at various research stations in the chickpea growing regions of Pakistan(Rasool et al. 2023).

Table 5. Performance of TG1305 as "Star Channa" in National Uniform Yield Trials

Year	**Site/ locations**	**(Yield kg/ha)**	
		TG1305	**Bittle-2016**
2018-19	PRI, AARI FSD	1613	1892
	ARS, Karak	1229	1233
	AZRI, Bhakkar	2400	2125
	AZRI, Bahawalpur	1290	1193
	AZRC, D. I. Khan	1258	1341
	BARI Chakwal	1132	1201
	GBRSS, KallurKot	1736	1431
	NARC, Islamabad	3245	2288
	NIAB, Faisalabad	1388	1417
	NIFA Peshawar	2486	2260

	QAARI, Larkana	1277	1132
	Average	**1732**	**1592**
	+/- % increase over checks	**09**	**-**
2019-20	**Site/ locations**	**(Yield kg/ha)**	
		TG1305	**Indus-2019**
	PRI, AARI Faisalabad	592	319
	ARS, Karak	643	1077
	AZRI, Bhakkar	1217	1077
	AZRI, Bahawalpur	1632	1875
	AZRC, D. I. Khan	890	914
	BARI, Chakwal	593	535
	GBRSS, KallurKot	2403	1681
	NARC, Islamabad	2004	1966
	NIAB, Faisalabad	939	1029
	QAARI, Larkana	2472	2181
	RARI, Bahawalpur	1979	1736
	Average	**1397**	**1308**
	+/- % increase over checks	**07**	**-**

Plant Protection

Reaction to Fungal Diseases

The resistance of the newly evolved variety Star Channa and control were tested against *Fusarium* wilt, root rot, iron chlorosis and *Ascochyta* blight at Arid Zone Research Institute, Bhakkar. The disease responses of TG1305 and Bittle-2016 (Check) against *Fusarium* wilt, root rot, iron chlorosis and *Ascochyta* blight are shown in Table-6. TG1305 and Bittle-2016 (Check) both showed resistance response with rating 3, against *Fusarium* wilt, root rot and iron chlorosis as shown in Table-5. The reaction of each genotype against *Fusarium* wilt with reference to resistance and susceptibility was revealed through Disease Rating Scale (DRS) by the scientist (Srivastava et al. 2021).While the reaction to *Ascochyta* disease was documented via DRS from 0 to 9 (Farahani et al. 2019, Gayacharan et al. 2020). A new developed strain TG1305 showed a resistant response with rating 3 for *Ascochyta* Blight, whereas Bittle-2016 (Check) showed a moderately resistant reaction with rating 5. Overall, TG1305 displayed a high level of resistance against *Fusarium* wilt, root rot and iron chlorosis and *Ascochyta* blight. These diseases reaction showcased that the genotype TG1305 has potential to mitigate the adverse effects of various diseases in chickpea cultivation. Similar results were also reported by the author(Basandrai et al. 2007).

Table 6. The reaction of TG1305 as "Star Channa" to fungus diseases

Fusarium wilt, root rot & iron chlorosis			*Ascochyta* Blight		
Score	Reaction	Genotype	Score	Reaction	Genotype
1	Highly resistant	-	0	Immune	-
3	Resistant	TG1305 Bittle-2016 (Check)	1	Highly resistant	-
5	Moderately resistant	-	3	Resistant	TG1305
7	Susceptible	-	5	Moderately resistant	Bittle-2016 (Check)
9	Highly susceptible	-	7	Susceptible	-
			9	Highly susceptible	-

Response of Candidate Variety TG1305 against Pod Borer Response of candidate cultivar TG1305 to pod borer infestation was assessed and compared with two control varieties including Bittle-2016 and

Bhakkar-2011. Larval population per meter of row was documented as 0.12 ± 0.05, with an average of 78.61 ± 4.56 pods per plant in strain TG1305, as shown in Table 7. Number of damaged pods per plant was recorded as 6.35 ± 0.85, resulting in a yield of 1220 ± 26.8 kg/ha. Whereas, the check Bittle-2016 showed a higher larval population per meter row (0.17 ± 0.02) with an average number of pods per plant (65.80 ± 4.26). Damaged pods per plant were 9.35 ± 1.25 and grain yield of 1050 ± 14.6 kg/ha were recorded, respectively. Similarly, Bhakkar-2011 (Check) had a larval population per meter row of 0.19 ± 0.04, with an average number of pods per plant of 68.55 ± 3.48. Damaged pods per plant were 8.63 ± 0.78 resulting in a grain yield of 1110 ± 21.4 kg/ha. Generally, the data showed that the strain TG1305 had a comparatively lower larval population and higher grain yield compared to the control varieties.

Table 7. Response of TG1305 against pod borer infestation

Genotype	**Larval Population /meter row**	**Average Pods/ Plant**	**Damaged Pods/ Plant**	**Yield/Plot ($kgha^{-1}$)**
TG1305	0.12±0.05	78.61±4.56	6.35±0.85	1220±26.8
Bittle-2016 (Check)	0.17±0.02	65.80±4.26	9.35±1.25	1050±14.6
Bhakkar-2011(Check)	0.19±0.04	68.55±3.48	8.63±0.78	1110±21.4
CV(%)	11.5	17.6	8.5	9.9
$LSD_{0.05}$	0.60	5.82	1.62	73.27

Results of Genetic Polymorphism Analysis Utilizing SSR Markers

Analysis was carried out to create a dendrogram / Cultivar Identification Diagram (CID) representing the relationships between several chickpea varieties (Fig. 1). Definitely, the varieties examined were Bhakkar-2011, Thal-2020, Rohi-Channa-20 and the Candidate variety TG1305. This analysis used the unweighted paired group method with arithmetic means (UPGMA) to create the dendrogram. On the horizontal axis (X-axis) of the CID, the genetic similarity coefficient between the different genotypes was presented. The coefficient ranged from 0.71 to 0.86 and reflected the degree of genetic similarity or dissimilarity among the chickpea varieties. The results of the CID analysis were observant and exhibited significant differences between the candidate variety TG1305 and the control varieties. In particular, the candidate variety TG1305 manifested significant dissimilarity compared to Rohi Channa-20 (37% dissimilarity), Thal-2020 (18% dissimilarity), and Bhakkar-2011 (23% dissimilarity). Basically, the CID provided a visual representation of genetic relationships among the chickpea varieties examined, emphasizing the distinctiveness of the candidate variety TG1305 from the reference varieties.

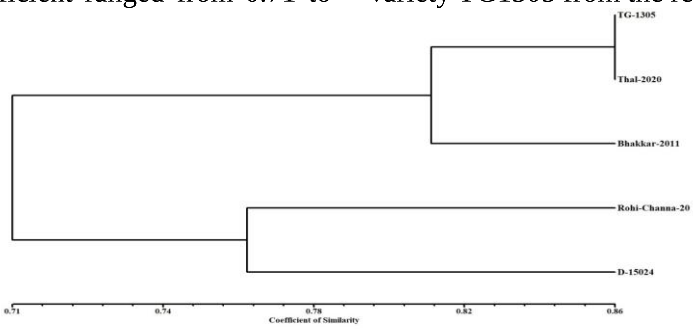

Fig. 1. Phylogenetic tree of Star Channa (TG1305) based on DNA fingerprinting by using SSR markers.

Quality Traits

Data comparing the composition of the two varieties or strains TG1305 and Bittle2016 (Check) were presented in Table 8. Each variety is categorized by its crude protein content, crude fat content and ash content. Crude protein mentions the total protein content, while crude fat represents the total lipid content and ash content designates the inorganic mineral content. In the case of "TG1305", the crude protein content is 23.9%, the crude fat content is 3.72% and the ash content 3.63%. In "Bittle-2016 (check)", however, the crude protein content is slightly lower 22.5%, crude fat content 3.15% and ash content 3.06%. Overall, TG1305 normally has a higher level of crude protein, crude fat and ash, indicating its better nutritional value in comparison to the Bittle-2016 check variety.

Table 8. Physio-chemical traits of Star Channa (TG1305)

Variety /stain	Ash (%)	Crude Fat (%)	Crude Protein (%)
TG1305	3.63	3.72	23.9
Bittle-2016 (check)	3.06	3.15	22.5

Agronomic Studies

Sowing Date Trial

This trial was conducted to determine the effects of different sowing dates on the yield performance of two chickpea strains TG1305 and Bittle-2016, over two consecutive years 2017-18 and 2018-19, as determined in Table-9. The trial included seven different sowing dates from October 1st to November 30thand recorded the yield attained for each sowing date to analyze the effect of planting timing on plant productivity. In both seasons, the highest yields were achieved when sowing around October 20th, gradually decreasing as sowing began into November. For TG1305, the highest yields were between 1790 kg/ha and 1850 kg/ha, while for Bittle-2016 these were between 1600 kg/ha and 1640 kg/ha. Overall, the trial emphasizes the crucial role of planting timing and suggests that an optimal planting timing for the selected chickpea genotype TG1305 and Bittle-2016 is in the range of October 20th (SD3) to October 30th(SD4) under normal agro-climatic conditions.

Table 9. Response to different sowing dates based on yield (kg/ha)

Year	Variety	SD1 Oct. 1st	SD2 Oct. 10th	SD3 Oct. 20th	SD4 Oct. 30th	SD5 Nov. 10th	SD6 Nov. 20th	SD7 Nov. 30th
2017-18	TG1305	888	1160	1850	1790	1630	1310	755
	Bittel-2016	815	1040	1640	1620	1490	1180	700
2018-19	TG1305	852	1200	1790	1760	1630	1290	680
	Bittle-2016	800	1170	1600	1640	1550	1150	630

Seed Rate Trial

This trial was conducted over two consecutive years, 2017-18 and 2018-19 with different seed rates from 50 kg/ha to 100 kg/ha and evaluated their impact on yield performance for the designated chickpea candidate variety TG1305 (Table 10). In the 2017-18 trial, different seed rates led to varying yield results. Initially with the lowest rate of 50 kg/ha, a yield of 900 kg/ha was attained. As the seed quantity increased, the yield also increased and was maximum 1100 kg/ha at a rate of 62 kg/ha, suggesting a positive correlation. Maximum yield (1720 kg/ha) was achieved at seed rate of 75 kg/ha. Beyond this, increasing seed rate to 87 kg/ha exhibited lessening returns, falling to 1100 kg/ha. At seed rate of 100 kg/ha, the yield cut down further to 890 kg/ha, suggesting that too high seed density had a negative impact on yield. Similar leanings were observed in the 2018-19 season, highlighting the importance of optimizing seed density. The optimum seed rate of 75 kg/ha was determined for the chickpea strain TG1305 under normal conditions. Similar, several authors(Machado et al. 2006, Nawange et al. 2016, Kumar et al. 2018, Loria 2022)informed that applying a seed rate of 75 kg/ha contributed to maximum crop productivity and income.

Table 10. Response to different seed rate

Seed Rate (kg/ha)	Yield (kg/ha)	
	1st year (2017-18)	2nd year (2018-19)
50	900	880
62	1100	1080
75	**1720**	**1775**
87	1100	1050
100	890	950

Fertilizer Requirements and Planting Geometry Studies In this experiment, various combinations of nitrogen and phosphorus fertilizers were used at different row spacing configurations and the resulting yields were noted. The recorded yield data deliver valuable understandings into the effects of fertilizers and plantings geometry on plant production. For the fertilizer factor of the trial, different doses of Nitrogen (N) and phosphorus (P) fertilizers were applied at rates ranging from 0 kg/ha to 23 kg/ha for both nutrients. The yield results represented a perfect trend towards increasing yields with higher fertilizer supplies (Table-11). Application of 23 kg/ha of both N and P gave higher yields compared to control. Moreover, the combination of 23 kg/ha N and 57 kg/ha P produced the highest yield among the fertilizer treatments. This emphasized the importance of balanced nutrient application for optimum plant growth, yield and yield contributing parameters. Application of 60 kg P2O5 resulted in best performance in all studying parameters and leading to maximum productivity and profitability of chickpea crop (Hussen et al. 2013, Singh et al. 2017).Regarding the factor planting geometry, various row spacing patterns of 30 cm, 45 cm and 60 cm were tested. Yield data showed that row spacing of 30 cm and 45 cm resulted in higher grain yields than row spacing of 60 cm. At the highest fertilizer rate 23 kg/ha N and 57 kg/ha P, the candidate variety TG1305 gave a higher grain yield of 1510 or 1450 kg/ha with a row spacing of 30 cm or 45 cm. The maximum yields were recorded by maintaining a row spacing of 30 cm in chickpea cultivation(Verma and Pandey 2008, Bhowmick et al. 2013, Chala et al. 2020, Loria 2022).

Table 11. Response to different fertilizer doses

NP Levels (kg/ha)		Yield (kg/ha)		
		Row spacing (cm)		
N	**P**	**30**	**45**	**60**
0	0	830	850	780
23	23	925	940	1025
23	46	1100	1160	850
23	**57**	**1510**	**1450**	**1150**
23	69	850	770	720

Optimization of Irrigation Schedule

Table 12 provides an overview of grain yield responses to different irrigation treatments and provides valuable assistance for irrigation planning for the chickpea candidate variety TG1305. Beginning with the control group (I_0), demonstrating rainfed conditions or no supplemental irrigation, grain yields of 199 kg/ha and 209 kg/ha were noted. This helped as a baseline against which the efficiency of succeeding irrigation treatments was estimated. In the first treatment (I_1), in which a single irrigation was carried out at the time of sowing, a significant increase in grain yield was observed compared to the control. Flood irrigation resulted in a grain yield of 692 kg/ha, indicating the significant impact of this initial irrigation on crop production. A significant enhancement was also observed in sprinkler irrigation with a yield of 642 kg/ha. The second treatment (I_2) includes two watering sessions in the sowing and flowering phases, resulting in even higher yields. Grain yields of 1112 kg/ha under flood irrigation and 1137 kg/ha under sprinkler irrigation was recorded. Irrigation should commence before flowering to avoid moisture deficit and mitigate the negative effects of high temperatures on grain size, quality and yield(Bray 2010).This proposes that timely irrigation applications, particularly during crucial growth phases, significantly increases crop yields. The high intensity treatment (I_3) included three irrigation sessions at the seeding, flowering and pod formation stages, using both sprinkler and flood irrigation systems. Despite the complication of this regime, the results showed a constant increase in grain yield. Remarkably, flood irrigation produced the highest grain yield of 1161 kg/ha, while sprinkler irrigation still had a grain yield of 1124 kg/ha. The author(Singh et al. 2016, Kirnak et al. 2017)found that the application of irrigation during the pod formation stage in chickpea grown in sandy loam soil can continuously increase yields and possibly serve as a water-saving substitute to wheat cultivation in regions with shortage of water supplies.

Table 12. Response to different irrigation levels

Treatments (Irrigation level)	Grain yield (Kg/ha)	
I_0	199 (Control)	209 (Control)
I_1	692 (Flood)	642 (Sprinkler)

I_2	1112 (Flood)	1137 (Sprinkler)
I_3	1161 (Flood)	1124 (Sprinkler)
CV(%) $LSD_{(0.05)}$	5.13 81.11	3.24 50.36

Morphological Character of Variety Star Channa

Botanical Description

Star Channa is a bold-seeded chickpea variety with good yield potential and strong resistance to major diseases. It performs better than the commonly grown varieties Bittal-2016, Bhakkar-2011 and Punjab-2008. The variety grows well in both irrigated and rainfed areas and shows a vigorous growth habit. Plants are semi-erect and reach about 65–68 cm in height. The stems are light green with medium hairiness and a moderate canopy. Usually, plants produce 4–5 primary branches, 10–12 secondary branches and 16–18 tertiary branches, although this can change depending on growing conditions. Leaves are green, with a rachis length of about 4.4 cm and 12–14 leaflets. Each leaflet is medium in size, measuring 13–15 mm long and 11–12 mm wide, with an acuminate tip and an obovate shape.

Flower, Pod and Seed Characteristics

Flower size is medium, pink in color. It takes 88-90 days to 50 percent flowering after sowing while flowering duration is 60-65 days. Pod size is medium having 2.9cm length, 1.5 cm width, 1.5 cm thickness and 3-4mm beak micro length. The number of pods varies from 75-80 with 1-2 seeds per pod while pod shattering is absent. Seed color is brown, dot less with ram headed shape and rough texture. Seed is bold, ram headed having 9.6mm, length, 8.0mm width, and 7.8mm thickness. 100 seed weight is 29-30gm. Potential yield is 3800-4000kg/ha^{-1}

Approval

In its 55th meeting held on September 20, 2021, the Punjab Seed Council (PSC) approved the strain TG1305, designated as Star Channa, for extensive commercial cultivation throughout Punjab, Pakistan. This decision is anticipated to yield substantial advantages for chickpea farmers in the area.

CONCLUSION

Star Channa (TG1305) is a remarkable desi chickpea variety distinguished by its exceptional yield, robust seeds, and built-in resistance to main chickpea diseases such as *Fusarium* wilt and *Ascochyta* blight. It has consistently outperformed other varieties by a notable margin in various trials, including station, adaptation, provincial and national yield assessments, showing a significant superiority. This remarkable achievement has attracted widespread attention. Due to this positive feedback, Star Channa is awaited with great excitement and enthusiasm by farmers. The widespread introduction of Star Channa is expected to have a significant impact on chickpea production in Pakistan. By selecting this variety for cultivation, farmers can help maintain and stabilize national chickpea production, meeting both local demand and potential export opportunities. Due to its disease resistance, Star Channa can reduce the need for chemical interventions to promote environmentally friendly agricultural practices. Essentially, Star Channa represents a valuable addition to the agricultural sector, offering a climate-friendly and disease-resistant variety that can thrive in diverse environments. Its introduction not only guaranteed higher yields and better crop quality, but also has the potential to reduce Pakistan's dependence on chickpea imports, thereby positively impacting the country's economy.

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Authors Contribution

Niaz Hussain (Principal Breeder) drafted the manuscript and performed data analysis, While Abdul Ghaffar, Muhammad Aslam, Khalid Hussain are co-breeder of this chickpea new variety Star Channa. Muneer Abbas and Muhammad Nadeem were responsible for plant protection measures. Muhammad Tariq Javeed, Zubeda Parveen and Fiaz

Hussain revised and edited the manuscript. Imran Habib performed DNA fingerprinting.

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