Research Article

Noor-2019: A High Yielding and Wilt Resistant Chickpea Kabuli (*Cicer arietinum* L.) Variety Developed through Introgression Breeding

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Abstract | Over the years, a crop variety grown on the commercial scale and under different conditions becomes vulnerable to various kinds of issues involving both biotic and abiotic plant stresses, alone or in combinations. This demands their substitution with new and improved genotypes possessing higher productivity and inherent resistance/tolerance against yield-limiting stresses. In this context, this editorial reports the development of a new chickpea kabuli variety "Noor-2019". This cultivar has improved yield potential, dietary elements (proteins, fat, ash), and more importantly, resistance against *fusarium* wilt and *ascochyta* blight compared to the existing varieties. The evolution of this strain commenced in 2002-03 cropping season by crossing K-90399 as a female parent with K-52582 as a male parent. The female parent had high yield potential, whereas the male parent had wilt resistance and was developed through introgression breeding using ILWC-126, an accession of *Cicer reticulatum*. Henceforth, the genetic variability was created to select for high yield and wilt resistant recombinants in subsequent generations. Resultantly, a uniform and high yielding progeny line PCK-09012, later designated as "Noor-2019" was selected and evaluated for yield, agronomy, and insect pests. This cultivar revealed a potential yield of 2882 kg ha^{-1} in testing phase and outperformed standard checks by producing 78.2%, 13.1%, and 28.8% higher grain yield in station, adaptation and national uniform yield trials, respectively. The plants of Noor-2019 are 60-65cm tall, semi-erect, and medium in canopy spread. Its grains are light brown, ram-headed, medium in size with a 100-seed weight of 25 g. Adoption of this cultivar across different climatic regions of Punjab, and other provinces could contribute in attaining self-sufficiency in local chickpea production as well as plummeting import bill.

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Introduction

Chickpea is the leading food legume of rainfed agricultural systems, globally as well as Pakistan (Naveed *et al*., 2019). They are planted mostly on poor soils with limited moisture availability under semi-arid and subtropical climatic conditions (Kaloki *et al*., 2019). Chickpea seeds are rich in vital dietary elements such as proteins, fats, essential amino acids, vitamins and minerals. Their natural capacity to fix atmospheric N improves soil health which helps them well to fit in different cropping patterns (Naveed, 2022).

The cultivated chickpea is associated with genus *Cicer* that encompasses one domesticated (*arietinum*) and forty-three wild species (Singh *et al*., 2021b). Lack of genetic diversity in this cultivated species restricts the anticipated genetic improvement crucial for withstanding complex issues undermining sustainable production (Singh *et al*., 2021c). The primary causes are restricted distribution of progenitor, genetic erosion during domestication process, and substitution of local landraces with genetically pure lines. These factors have also limited the capacity of chickpea to tolerate various biotic (blight, wilt) and abiotic (drought, heat, cold etc.) stresses (Samineni *et al*., 2021). To overcome these issues, concerted breeding strategies are needed to be deployed for systematically creating and exploring diverse plant material (Arriagada *et al*., 2022). For this purpose, introgression breeding can be used as a tool to broaden the crop genetic base and to achieve desired genetic improvement in targeted traits (Arriagada *et al*., 2022). The issue of sterility in interspecific hybrids can be addressed by using *C. reticulatum* as a pollen parent with cultivated chickpea (Ceylan *et al*., 2019).

In world chickpea scenario, Pakistan is a key player in acreage, production and consumption (FAOSTAT, 2021). Annually, the Punjab province alone contributes about 90% of acreage and 80% of total production of Pakistan (Naveed *et al*., 2019). Nearly 85% share of Punjab is primarily planted in Thal region, where summer rainfalls are the only source of receding soil moisture available for the entire cropping period. Therefore, as the plant growth advances, the chickpea crop faces moisture stress during the two most crucial yield defining phases i.e. flowering and podding termed as terminal drought (Gaur *et al*., 2019; Naveed, 2022). Consequently, the total production of Pakistan is low, inconsistent and much lower to the domestic requirements despite being the second largest in chickpea acreage, globally (FAOSTAT, 2021). Further, various stresses such as disease, drought, heat, cold etc. when occur alone or in different combinations adversely affect chickpea crop causing severe production losses (Naveed *et al*., 2019, 2020). For example, *fusarium* wilt alone can cause 12 M rupees production losses in chickpea (Fatima *et al*., 2022a, b). This disease caused by *fusarium oxysporum* is widespread in subcontinent and adjoining countries (Gopalakrishnan and Srinivas, 2019). It transmits/spreads through the soil, infects roots and impedes food supply to stem and other plant parts above-ground by blocking xylem vessels (Motagi *et al*., 2020; Nathawat *et al*., 2020). Likewise, chickpea blight, another devastating disease caused by *ascochyta rabiei* appears under rainy, wet conditions, can inflict 50-70% production losses (Javaid *et al*., 2020; Zhang *et al*., 2019). It can emerge in an epidemic form at any crop stage under the environments conducive for its development such as higher rainfall followed by increase in temperature and at times may cause complete crop damage with no yield at all (Crutcher *et al*., 2022; Moarrefzadeh *et al*., 2022; Nalçacı *et al*., 2021).

To overcome these issues, development and availability of stress-tolerant cultivars is the most effective and least expensive way forward (Naveed, 2022; Naveed *et al*., 2020). Therefore, developing new, high yielding and stress-tolerant genotypes is the ultimate objective of any crop-breeding program (Arriagada *et al*., 2022). However, this is not a simple/direct process, instead a lengthy one expanding to more than 10 years' subject to crop type and breeding methods used. This may comprise development of parents or selection from gene-pool followed by hybridization, raising of filial generations (F_1 to F_6), selection of desirable plants/uniform lines, and evaluation in different trials determining yield potential, stability/fixing of agro-morphological traits, response to disease and agronomic production package followed by approval process (Naveed *et al*., 2020; Raina *et al*., 2019). However, a cultivar becomes susceptible overtime to various types of stresses affecting yield potential and necessitating replacement with genetically improved genotypes (Choudhary *et al*., 2022; Folta, 2019).

In this regard, local legume breeders have made considerable progress in developing new and improved chickpea cultivars possessing stress tolerance and better yielding ability (Naveed *et al*., 2020). The parental source of all the chickpea varieties evolved so far in Pakistan was the cultivated species *C. arietinum*. Efforts were made to accumulate desirable traits from *C. reticulatum* into the cultivated promising genotypes. This research article reports the development of a new chickpea kabuli cultivar with one of the two parents evolved from the wild progenitor.

Materials and Methods

The selection of parents for the development of Noor-2019 was made based on yield potential and disease resistance. For this purpose, two local strains comprising K-90399 (yield potential = 3000 kg ha^{-1}) as female parent while K-52582 (wilt resistant with yield potential = 1300 kg ha^{-1}) as male parent were used in hybridization.

Development of parents
Entry K-90399 designated here as a female parent was a direct selection from a segregating population and developed using the bulk method of plant selection. The male parent K-52582 resulted from introgression breeding between another local line K-00952 and ILWC-126 from the wild progenitor, *Cicer reticulatum*, used as a pollen parent. The F_1 hybrid was backcrossed with recurrent/female parent K-00952. In succeeding generations, the progenies were selected for desirable traits and re-crossed with the recurrent parent. This process continued until the homozygous uniform lines were produced. These lines were tested for yield and disease response. Consequently, an advanced line K-52582 was identified as *fusarium* wilt resistant. This line was subsequently used as the source of resistance in breeding schemes.

Hybridization (F_0)
To create desirable recombinants, various cross combinations involving wilt resistant source K-52582 were attempted during 2002-03 at Pulses Research Institute (PRI), AARI, Faisalabad, Pakistan. To facilitate the crossing work, both male and female parents were grown side-by-side in equal row lengths. At the commencement of anthesis phase (February-March), immature and unopened flower buds that emerged on female parent plants were emasculated and pollinated manually with the help of forceps (Dixit *et al*., 2022; Kiran *et al*., 2019). After emasculation, the pollens collected from male plants were dusted immediately on female plants. This was practiced in the morning between 9:00 to 11:00 am to prevent self-fertilization. Once the crossed buds developed into pods and reached maturity, they were detached from the plant and thrashed to get F_0 seeds. The breeding and evaluation history of Noor-2019 is given in Table 1.

Raising of filial generations (F_1 to F_6)
In 2003-04, the seeds harvested from F_0 plants were field planted on inside rows of both the parental lines for raising F_1 hybrid plants. All these plants were grown in equal lengths of 4m by maintaining 15 cm plant-to-plant (P-P) and 30 cm row-to-row (R-R) standard distances. The seeds obtained from F_1 plants were bulked and used to raise F_2 population on the optimal soil conditions in the following cropping season. Single plant selections (SPS) were made phenotypically starting from F_2 to F_5 generations and sown in plant to row progenies using pedigree method of plant breeding. From F_6 generation, a homozygous and uniform progeny line was selected and bulked for further testing in yield and other supporting trials. Filial generation three (F_3) and five (F_5) were raised on wilt sickbed to identify wilt resistant segregants, while F_4 and F_6 generations were planted on optimal soil conditions to identify high yielding recombinants.

General experimental details
The experimental sites consisted of both rainfed and irrigated conditions. Under rainfed conditions, no irrigation was applied during the entire cropping period. In comparison, one irrigation of 45 mm was applied at 50% flowering under irrigated conditions. The trials were sown between recommended planting window i.e., 15th October to 15th November. One bag of di-ammonium phosphate fertilizer per acre was applied at the time of land preparation whereas all other practices (weeding/hoeing, irrigation, chemical spray) were kept same for agronomic (irrigation, spacing) and yield trials. No chemical spray was done in entomological experiments to assess pod borer infestation under natural conditions. All these trials were laid out in a randomized complete block (RCB) design with three replications and maintaining standard distances of 30 cm R-R and 15 cm P-P. Two seeds were placed per hole throughout the trials to maintain per plot plant population, which were thinned after 20-25 days to one healthy seedling after germination occurred.

Table 1: *Developmental history of PCK-09012 as Noor-2019.*

Year	Events	Operation/action
	Filial generations	
2002-03	Hybridization	Harvested and thrashed F_0 seed
2003-04	F_1 (Filial generation-one)	Harvested and thrashed F_1 seed
2004-05	F_2 (Filial generation-two)	Performed single plant selection (SPS)
2005-06	F_3 (Filial generation-three)	Planted plant-to row progenies
2006-07	F_4 (Filial generation-four)	Planted plant-to row progenies
2007-08	F_5 (Filial generation-five)	Planted plant-to row progenies
2008-09	F_6 (Filial generation-six)	Selected and bulked uniform lines
	Yield trials	
2009-10	Preliminary yield trials (PYTs)	Recorded yield data
2010-11	Advanced yield trials (AYTs)	Recorded yield data
2011-12	Micro yield trials (MYTs)	Recorded yield data
2012-13	Co-operative yield trials (CYTs)	Recorded yield data
2014-16	National uniform yield trials (NUYTs)	Recorded yield data
2013-16	Distinguishing uniformity stability (DUS) studies	Recorded data on qualitative and quantitative plant traits
	Supporting trials	
2013-15 2016-18	Irrigation and sowing date trials	Recorded grain yield at different irrigation levels and sowing dates
2015-17	Disease studies	Recorded reaction to wilt and blight diseases
2015-17	Pod borer studies	Recorded gram pod borer infestation
2015-17	Grain quality analysis	Determined protein, fat and ash concentration
	Commercial release formalities	
2017-18	Spot examination	Recommended by Experts Sub-Committee
2019	Presented in Punjab Seed Council (PSC)	Approved for commercial cultivation

Yield trials

A uniform plot size of 4×1.2 m^2 was kept at all the locations over the years in station [preliminary (PYTs), advanced (AYTs)] and adaptability [micro (MYTs), co-operative (CYTs)] yield trials, while a plot size of 4×1.8 m^2 was maintained in national uniform yield trials (NUYTs). Each trial comprised at least one standard check variety for comparing the performance of candidate line. The yield data were recorded on per plot (g) basis, which was later converted to kg ha^{-1}.

DUS studies

For distinguishing uniformity stability (DUS) studies, qualitative and quantitative data were collected from all yield trials following the procedure given in the chickpea descriptor (Asati *et al*., 2023).

Irrigation and sowing date trials

The optimum number of irrigations required for harvesting good yield was determined at the already established production technology. In zero irrigation trial, no irrigation was applied during the entire cropping period and the crop matured at the receding soil moisture received from rainfalls. At irrigation level one, the sole irrigation of 45 mm was applied at the start of anthesis, while in irrigation level two, one irrigation of 45 mm was applied at the beginning of anthesis whereas the second irrigation of 30 mm at the pod filling stage. Studies were also conducted to determine the optimum sowing date for harvesting good yield following the same standard practices given under the heading "general experimental details". However, based on the previous field experiences, two irrigations were applied, one at the start of anthesis while the other at the pod filling stage.

Disease reaction

To screen segregating F_3 and F_5 recombinants against *fusarium* wilt, individual single plants were sown on a previously developed wilt sick bed and scored for disease response. However, the trials to study *fusarium* wilt and *ascochyta* blight disease reaction were laid out using augmented design with two replicates and a plot size of 0.3 m^2 for each entry. The *fusarium* wilt experiments were conducted on a natural wilt sick bed developed by continuous building up of inoculum. A susceptible check named "AUG-424" was planted after every two-test entries on both sides for building inoculum pressure. All the susceptible lines exhibited 100% wilt attack confirming field infestation of the highest level. The first reading of wilt frequency was done 30 days after sowing, followed by ten days interval between recordings till the crop matured. The reaction of each genotype in terms of resistance and susceptibility was determined following the disease rating scale (DRS) used previously (Srivastava *et al*., 2021). However, for *ascochyta* blight studies, a plastic tunnel with a sprinkler system was used for creating artificial mist (> 90%) conducive for the appearance of this disease. Punjab-1, a spreader/ check was planted after every two test entries for recording the severity/ intensity of *ascochyta*. All the plants were inoculated by spraying at 8-10 leaf stage, whereas scoring was done on 0 to 9 scale after about fourteen days of inoculation (Farahani *et al*., 2019; Gayacharan *et al*., 2020).

Pod borer infestation studies

The chickpea pod borer is a serious threat to chickpea production and can cause yield losses up to an economic threshold level. Therefore, experiments were conducted to assess the percentage of pod borer infestation. Standard practices were kept similar as described under the heading general experimental details, however, no chemical spray was applied. The infestation %age was worked out by counting total pods and infested pods per plant.

Grain quality analysis

To determine crude protein, fat and ash contents, three seed samples were taken randomly from the seed source and processed as per procedure employed by previous researchers (Varol *et al*., 2020).

Statistical analysis

Data collected from all the trials (yield, agronomy, pathology, entomology and quality) were analyzed and tested for significance at $P < 0.05$ using Genstat software v.14.1 (Payne *et al*., 2011). Data presented in tables are the mean values across each location along with the value of least significant difference (LSD 0.05). Percent increase/ decrease over checks was also computed to explain the results.

Results and Discussion

Breeding phase

Several cross combinations were tried in 2002-03 using female genotypes from *Cicer arietinum*, and a male genotype (K-52582) developed from both *C. arietinum* and *C. reticulatum* species. About 100 pollinations were done in each of those cross combinations. Cross number (C. #) fifteen (15) developed from parental genotypes K-90399 × K-52582 set the highest thirteen F_0 seeds. These seeds were field-planted next season, one in a hole, to raise thirteen F_1 hybrid plants on optimal soil conditions. The seeds harvested from these thirteen F_1 single plants were harvested, thrashed, and bulked to raise three hundred twenty-one (321) F_2 single plants on the optimal soil conditions. Out of these 321 F_2 single plants, 315 single plants were advanced to the F_3 generation in plant-to-row progenies on a wilt sick bed to identify *fusarium* wilt resistant recombinants. Only five F_3 recombinant plants survived, while the rest were infected with wilt and died. The seeds harvested from those five single plants were advanced to filial generation-four (F_4) on an optimal soil condition and in plant-to-row progenies with a total of 146 single plants to identify recombinants with higher yield potential. From this F_4 population, one hundred and two (102) high yielding single plants were selected and re-sown on wilt sickbed to raise the F_5 population. Eighty (80) disease-free and vigorous single plants were selected from the F_5 population and advanced to the F_6 generation on optimal soil conditions (Table 2). From the F_6 population, a uniform and higher-yielding progeny line PCK-09012 with pedigree C.15/15/15/105/98/80/12 was identified and bulked for further testing.

Evaluation phase

Yield trials: Thirty-two yield evaluation trials were conducted involving candidate line PCK-09012 under different climatic conditions from 2009-10 to 2015-16. In station (PYTs and AYTs) yield trials (SYTs), line PCK-09012 yielded in the range of 701 to 2882 kg ha^{-1} in comparison to 382 to 529 kg ha^{-1} of Noor -91 and 1208 to 1979 kg ha^{-1} of Punjab Noor, the check varieties. The average grain yield of 1687 kg ha^{-1} of PCK-09012 in SYTs was significantly higher compared to 1025 kg ha^{-1} of standard checks (Table 3). The same was observed in adaptability (MYTs and CYTs) yield trials (AdYTs) conducted across 10 environments during 2011-13 (Table 4).

Table 2: *Detail of breeding phase/filial generations of PCK-09012 as Noor-2019.*

Filial generation	Single plants studied	Single plants selected	Operation/action
F_0	-	-	Parent genotypes hybridized and >100 flower buds pollinated
F_1	13	13	Plants raised under optimal soil/field conditions
F_2	321	315	Plants raised under optimal soil/field conditions
F_3	315	5	Plants raised on a wilt sick bed under field conditions
F_4	146	102	Plants raised under optimal soil/field conditions
F_5	102	80	Plants raised on a wilt sick bed under field conditions
F_6	80	-	Plants raised under optimal soil/field conditions

Table 3: *Grain yield (kg/ha) of PCK-09012 (Noor-2019) in station yield trials (SYTs).*

Year	Trial/Location	Check		PCK-09012	+/- Over check (%)	LSD (0.05)
2009-10	PYTs-Preliminary yield trials					
	Faisalabad/AARI	Noor-91	382	701	83.5	20.6
	Kallurkot/GBRSS		529	1146	116.6	12.9
	+/- Over check (Av. %)				100.3	
2010-11	AYTs-Advanced yield trials					
	Faisalabad/AARI	Punjab Noor	1208	2017	67.0	7.6
	Kallurkot/GBRSS		1979	2882	45.6	8.3
	+/- Over check (Av. %)				56.3	
	Pooled average		1025	1687	78.2	12.4

Irrigated locations: Faisalabad; Rainfed locations: Kallurkot; LSD value shows significant differences between check(s) and candidate line.

Table 4: *Grain yield (kg/ha) of PCK-09012 in adaptation yield trials (AdYTs).*

Year	Trial/Location	Check		PCK-09012	+/- Over check (%)	LSD (0.05)
2011-12	MYTs-Micro yield trials					
	Faisalabad/AARI	Punjab Noor	2428	2675	10.2	160.1
		CM-2008	2379		12.4	
	Kallurkot/GBRSS	Punjab Noor	1875	2118	13.0	217.6
		CM-2008	2083		1.7	
	+/- Over check (Av. %)				9.3	
2012-13	CYTs-Co-operative yield trials					
	Faisalabad/AARI	Punjab Noor	1636	2196	34.2	198.7
		CM-2008	1214		80.9	
	Faisalabad/NIAB	Punjab Noor	2241	2089	-6.8	302.2
		CM-2008	2540		-17.8	
	Kallurkot/GBRSS	Punjab Noor	1444	1806	25.1	133.7
		CM-2008	1104		63.6	
	Bhakkar/AZRI	Punjab Noor	2108	1458	-30.8	275.0
		CM-2008	2233		-34.7	
	Karor/ARS	Punjab Noor	1150	1301	13.1	114.2
		CM-2008	1204		8.1	
	Bahawalpur/RARI	Punjab Noor	2188	2083	-4.8	230.4
		CM-2008	2882		-27.7	
	Sahowali/PRSS	Punjab Noor	1337	1965	47.0	249.9
		CM-2008	1035		89.9	
	Fatehjang/BARS	Punjab Noor	1172	1084	-7.5	253.1
		CM-2008	1170		-7.4	
	+/- Over check (Av. %)				14.0	
	Pooled average		1771	1878	13.1	213.5

Irrigated locations: Faisalabad (AARI and NIAB), Bahawalpur; Rainfed locations: Kallurkot, Bhakkar, Karor, Sahowali and Fatehjang; LSD value shows significant differences between check(s) and candidate line.

Table 5: *Grain yield (kg/ha) of PCK-09012 (Noor-2019) in national uniform yield trials (NUYTs).*

Year	Location	Noor-2013 (Check)	PCK-09012	+/- Over check (%)	LSD (0.05)
2014-15	Faisalabad/AARI	319	838	162.7	
	Faisalabad/NIAB	544	517	-5.0	
	Kallurkot/GBRSS	778	1255	61.3	
	Fatehjang/BARS	373	356	-4.6	
	Bhakkar/AZRI	558	638	14.3	
	Larkana/QAARI	227	454	100	
	Bahawalpur/RARI	1366	1644	20.4	
	DI Khan/AZRI	1017	911	-10.4	
	+/- Over check (Av. %)			42.3	179.9
2015-16	Faisalabad/AARI	1627	1814	11.5	
	Faisalabad/NIAB	397	507	27.7	
	Kallurkot/GBRSS	1824	1963	7.6	
	Fatehjang/BARS	1508	1379	-8.6	
	Bhakkar/AZRI	1760	1824	3.6	
	Larkana/QAARI	1051	930	-11.5	
	DI Khan/AZRI	1895	1900	0.3	
	Karak/ARS	1799	1897	5.4	
	Islamabad/NARC	179	401	124	
	Chakwal/BARI	1028	951	-7.5	
	+/- Over check (Av. %)			15.3	195.5
	Pooled average	1014	1121	28.8	187.7

Irrigated locations: Faisalabad (AARI andNIAB), Bahawalpur; Rainfed locations: Kallurkot, Bhakkar, Larkana, Fatehjang, DI Khan, Karak, Islamabad and Chakwal; LSD value shows significant differences between check and candidate line.

In MYTs, PCK-09012 achieved grain yield of 2118 and 2675 kg ha^{-1} and surpassed both checks, Punjab Noor (1875 and 2428 kg ha^{-1}) and CM-2008 (2083 and 2379 kg ha^{-1}). In CYTs, PCK-09012 produced yield in the range of 1084 to 2196 kg ha^{-1} compared to 1172 to 2241 kg ha^{-1}of Punjab Noor and 1035 to 2882 kg ha^{-1} of CM-2008. In AdYTs, the average yield of 1878 kg ha^{-1} of PCK-09012 was about 2.5 maunds higher than both the standards (1771 kg ha^{-1}). Similar to SYTs and AdYTs, the performance of PCK-09012 in national uniform yield trials (NUYTs) was better than newly approved check variety at that time, Noor-2013 (Table 5). Over a total of eighteen locations across two years, PCK-09012 produced an average grain yield of 1121 kg ha^{-1} compared to 1014 kg ha^{-1} of the standard check with a yield difference of 107 kg ha^{-1}.

Table 6: *Qualitative and quantitative traits of PCK-09012 (Noor-2019) as revealed by distinguishing uniformity stability (DUS) studies conducted during 2013-16 (Numeric data averaged).*

	Traits	Noor-2013 (C)	PCK-09012
a	**Stem**		
1	Height	60-65cm	60-65cm
2	Growth habit	Semi erect to semi-spread	Semi erect
3	Canopy type	Wide	Medium
4	Stem colour	Light green	Light green
5	Primary branches	4-5	2-4
6	Secondary branches	7-10	3-7
b	**Leaf**		
1	Colour	Green	Green
2	Leaflets per leaf	15	15-17
3	Leaflets size	Large	Medium
4	Hairiness	Medium	Medium
c	**Flower**		
1	Colour	White	White
2	Size	Large	Medium
3	Days to 90% flowering	110-115	115-120
4	Days to maturity	140-150	150-155
d	**Pod**		
1	Size	Large	Medium
2	Shattering	Absent	Absent
3	Pods per plant	60-70	70-80
4	Seeds per pod	1-2	1-2
e	**Seed**		
1	Shape	Ram's head	Ram's head
2	Colour	Beige	Light brown
3	100-seed weight	34 gm	25 gm
f	Distinguishing features	Bold seed, high yielding	Pods on tertiary branches, high yielding, wilt and blight resistant

Various plant characteristics including agronomic, morphological and seed traits were also recorded (Table 6). Line PCK-09012 revealed distinctiveness compared to check (Noor-2013) in stem (growth habit, canopy spread, primary and secondary branches per plant), leaf (leaflets number and size), flower (size, days to anthesis and maturity), pod (size, pods per plant and seeds per pod) and seed (colour and 100-seed weight) characteristics. Differences in disease (wilt, blight) reaction were also noticed. Although Noor-2013 was better in some of the parameters such as primary and secondary branches, and 100-seeds weight etc., however, PCK-09012 had excelled in most crucial yield determining trait i.e. pods per plant (60-70 versus 70-80). The candidate variety also bears podding on tertiary branches, has better resistance against *fusarium wilt* and *ascochyta blight*, and has longer cropping period (140-150 versus 150-155) which helps to fill more number of pods, ultimately higher grain yield than Noor-2013.

Table 7: *Grain yield (kg/ha) of PCK-09012 (Noor-2019) at different irrigation levels during 2013-15.*

No. of irrigations	Punjab Noor (Check)	PCK-09012	+/- Over check (%)	LSD (0.05)
Zero	1512	1617	6.9	
One	1477	1639	11.0	
Two	1958	2064	5.4	
Pooled average	1649	1773	7.8	18.5

LSD value shows significant differences between check and candidate line.

Irrigation and sowing date trials

The response to different irrigation levels of PCK-09012 was also determined (Table 7). At zero (rainfed) irrigation, PCK-09012 performed (1617 kg ha^{-1}) better compared to the check Punjab Noor (1512 kg ha^{-1}). At irrigation one applied at the start of anthesis, the candidate line responded positively to the sole irrigation and produced 27 kg ha^{-1} more grains than at zero irrigation. However, the performance of standard check at irrigation one was disappointing causing more than 100 kg ha^{-1} yield reduction compared to zero irrigation. However, the candidate and check varieties responded well to two irrigations applied at the anthesis and pod filling stages, respectively. Whereas PCK-09012 achieved 106 kg ha^{-1} more grain yield in comparison to check Punjab Noor. The cumulative average at all three irrigation levels revealed a 1773 kg ha^{-1} grain yield of PCK-09012 compared to 1649 kg ha^{-1} of Punjab Noor. The response of candidate variety to different sowing dates was also studied (Table 8). At sowing date one (2nd week of October), PCK-09012 produced 1644 kg ha^{-1} grain yield in comparison to 1478 kg ha^{-1} of check Noor-2013. Both the genotypes had the highest grain yield at sowing date two conducted at the start of 4th week of October. However, PCK-09012 achieved 2076 kg ha^{-1} grain yield in comparison to 1838 kg ha^{-1} of Noor-2013. At sowing date three (2nd week of November), the performance of candidate and check variety was lower in comparison to the second sowing date but higher than the first sowing date. On this planting date, PCK-09012 produced a grain yield of 1723 kg ha^{-1} compared to 1519 kg ha^{-1} of Noor-2013. On overall basis (average of three sowing dates), PCK-09012 produced 1814 kg ha^{-1} grain yield than 1612 kg ha^{-1} of standard Noor-2013.

Table 8: *Grain yield (kg/ha) of PCK-09012 (Noor-2019) at different sowing dates during 2016-18.*

Sowing date	Noor-2013 (Check)	PCK-09012	+/- Over check (%)	LSD (0.05)
October 2nd week	1478	1644	11.2	
October 4th week	1838	2076	12.9	
November 2nd week	1519	1723	13.4	
Pooled average	1612	1814	12.5	14.8

LSD value shows significant differences between check and candidate line.

Disease reaction studies

The disease studies on *fusarium* wilt and *ascochyta* blight were conducted under wilt sickbed and plastic tunnel conditions, respectively (Table 9). Genotype PCK-09012 exhibited a distinctive response regarding disease resistance, an important attribute and requirement to fit in different cropping systems. This new line was declared as resistant (R) with DRS of 3 in comparison to 5 of moderately resistant (MR) of check Punjab Noor. For *ascochyta* blight, the candidate variety and the standard check were found as moderately resistant (MR) under the disease rating scale of 5.

Table 9: *Disease studies of PCK-09012 (Noor-2019) to fusarium wilt and ascochyta blight during 2015-17.*

***Fusarium* wilt**			***Ascochyta* blight**		
Grade	Reaction	Genotypes	Grade	Reaction	Genotypes
1	Highly resistant	-	0	Immune	-
3	Resistant	PCK-09012	1	Highly resistant	-
5	Moderately resistant	Punjab Noor (C)	3	Resistant	-
7	Susceptible	-	5	Moderately resistant	PCK-09012 Punjab Noor (C)
9	Highly susceptible	-	7	Susceptible	-
			9	Highly Susceptible	-

Pod borer infestation studies

The results of pod borer infestation %age under natural conditions revealed significantly lesser infestation of 6.3% on PCK-09012 compared to 7.5% of Punjab Noor (Table 10).

Table 10: *Infestation of gram pod borer on PCK-09012 (Noor-2019) during 2015-17.*

Entries	No. of pods studied	Pods # infected	Infected %age
PCK-09012	80	5	6.3
Punjab Noor (check)	80	6	7.5
LSD (0.05)			0.45

LSD value shows significant differences between check and candidate line.

Grain quality analysis

Grain quality greatly contributes in the success of a cultivar in terms of market value and consumer preference. This analysis revealed that line PCK-09012 has a higher percentage of dietary elements like crude protein (23.20% vs 19.70%), crude fat (4.06% vs 3.78%) and ash (3.42% vs 3.37%) in comparison to check variety (Table 11).

Table 11: *Grain quality analysis of PCK-09012 (Noor-2019) during 2015-17.*

Entries	Crude protein (%)	Crude fat (%)	Ash (%)
PCK-09012	23.2	4.06	3.42
Noor-2013 (check)	19.7	3.78	3.37
LSD (0.05)	0.39	0.22	0.03

LSD value shows significant differences between check and candidate line.

The exploitation of plant genetic resources with little success is one of the reasons for lack of improvement in productivity and production potential against various stresses (Perrino and Perrino, 2020). However, the creation of useful variation for achieving genetic improvement requires incorporation of elite sources of resistance in breeding schemes (Sharma *et al*., 2019; Singh *et al*., 2022). For this reason, the role of wild relatives being the source of resistance to multiple stresses becomes crucial in crop improvement. Whereas, their deployment in breeding programs is limited due to various genetic bottlenecks (Chandora *et al*., 2020; Perrino and Perrino, 2020). Pre-breeding offers the prospect to overcome these issues through the introgression of desirable traits from wild relatives to readily crossable genetic backgrounds (Coyne *et al*., 2020; Kashyap *et al*., 2022). In this content, the evolution of Noor-2019 is the indirect outcome of introgression breeding. The male parent (K-52582) used to produce F_1 hybrid plants carries *fusarium* wilt resistant genes from wild progenitor *Cicer reticulatum*. This wild relative was reported previously to carry source of resistance against various biotic stresses, including *fusarium* wilt (Chrigui *et al*., 2020; Reen *et al*., 2019; Toker *et al*., 2021; Vance *et al*., 2021).

During the 20th century, the achievements made in the field of plant breeding, especially in evolution of new cultivars with desirable traits, are remarkable (Altman *et al*., 2021; Naveed *et al*., 2019; Singh *et al*., 2021a). The knack of identifying distinct, desired traits and combining them into new or targeted genotypes is the principal feature of traditional crop breeding (Fasoula *et al*., 2020). The genetic gain/ improvement made over time by this part of plant breeding in realizing sustainable crop productions are stupendous (Akhatar *et al*., 2022; Begna, 2021). A number of chickpea varieties in Pakistan and other parts of the world have been developed using this scheme (Duarte, 2022; Khan *et al*., 2023; Naveed *et al*., 2020; Rasool *et al*., 2023). The new cultivar, Noor-2019, also evolved through this procedure, performed good and regularly surpassed standard checks in its testing stage. Noor-2019, on average, out-yielded respective checks and produced 78.2% higher yield in SYTs, with 100.3% in PYTs and 56.3% in AYTs. In AdYTs, the candidate genotype produced an overall 13.1% higher average yield compared to checks, with 9.3% in MYTs and 14.0% in CYT. Further, in two years of testing at the national level (NUYTs), Noor-2019 yielded 42.3% in 2014-15 and 15.3% in 2015-16 over the standards indicating its potential yield and adaptation across varied environmental conditions (Rasool *et al*., 2023). Moreover, a candidate line has to prove its worth in different trials over competing checks for commercial release. In this regard, Noor-2019 exhibited its potential over a series of trials conducted across a range of environments and its approval for general cultivation is in line with previously released chickpea cultivars in Punjab, Pakistan (Khan *et al*., 2023; Naveed *et al*., 2020; Rasool *et al*., 2023). This new cultivar also performed equally well at all the irrigation levels i.e. zero, one and two, however, for a good harvest, two irrigations are recommended, one each at the start of anthesis and pod filling stages for optimum yield harvest (Naveed *et al*., 2020).

Several factors contribute in the formation of grain yield and seeding at the best time greatly influences final crop production (Basu and Parida, 2023; Richards *et al*., 2022; Shah *et al*., 2020). The data revealed that sowing during the last-week of October to the first week of November at the already established distance of 15cm P-P and 30cm R-R and an application of one bag of DAP (di-ammonium phosphate) fertilizer at the time of land preparation is best for achieving maximum production of Noor-2019.

Furthermore, this strain's most important genetic improvement over the previously approved local chickpea cultivars is the inbuilt resistance against *fusarium* wilt and *ascochyta* blight. The versatility of new candidate variety on disease reaction can further be judged from the comparative performance of standard checks in yield trials. This indicated the potential areas of cultivation of this strain on different soil types with conditions conducive for disease incidence (Khan *et al*., 2023; Maphosa *et al*., 2020; Rasool *et al*., 2023). Besides, the quality analysis revealed that the new variety has the higher concentration of dietary elements (protein, fat and ash) and can be considered as an added advantage in addition to higher yield potential and disease resistance.

Figure 1: *The grains of Noor-2019.*

Recording of quantitative and qualitative data of PCK-09012 over the years under DUS studies revealed its plant height in the range of 60-65cm with a light green stem akin to check Noor-2013. However, it has a semi-erect plant type compared to semi-erect to semi-spread of check variety. It has 2-4 primary and 3-7 secondary branches per plant with pods set on tertiary branches. It has 15-17 medium-sized leaflets with moderate pubescence. It takes 115-120 days for 90% flowering and 150-155 days for physiological maturity. It produces 70-80 pods per plant, with 1-2 seeds per pod. Pods are medium in size with pod shattering absent and 100-seed weight of 25 g with light brown seed coat colour (Figure 1). Noor-2019 exhibited adaptation to both rainfed and irrigated regions with 2882 kg ha^{-1} potential yield and 1360 kg ha^{-1} average yield. The candidate variety got second and first position in NUYTs conducted over 2014-15 and 2015-16 cropping seasons. The ideotype of Noor-2019 as revealed by plant architecture is suitable for machine harvesting (Khan *et al*., 2023; Mewada *et al*., 2019).

Conclusions and Recommendations

Introgression followed by traditional plant breeding can be exploited for improving various desirable plant traits (yield, disease, quality etc.) in cultivated chickpea. Noor-2019 is an outcome of this breeding approach and possesses higher yield potential, dietary elements and inherent tolerance against most prevalent chickpea diseases (wilt and blight) in Pakistan. This cultivar demonstrated its worth in a series of trials and consistently out-performed standard checks. Adoption of Noor-2019 on a broad-acre will certainly contribute in achieving sustainability in local chickpea production, hence continual availability of quality protein for masses.

Registration

Noor-2019 was approved for commercial cultivation by Punjab Seed Council, Govt. of the Punjab, Lahore, Pakistan in its 51st meeting vide letter No. PSC/HQ-Coord/19/44/2013 dated 13.09.2019.

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Novelty Statement

Noor-2019 is a high yielding and disease resistant chickpea kabuli variety bearing pods on tertiary branches and is suitable for cultivation to both rainfed as well irrigated conditions.

Author's Contributions

Muhammad Nadeem: Done statistical analyses and contributed to write-up.
Muhammad Naveed: Lead breeding and evaluation phase, manuscript write-up.
Muhammad Shafiq: Involved in breeding and evaluation phase, supervised all other activities.
Irfan Rasool: Involved in hybridization and advancement of filial generations.
Muhammad Afzal Zahid: Involved in breeding, evaluation and approval phases.

Conflicts of interest
The authors of this manuscript declare that the present research was carried out in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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