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RESEAERCH ARTICLE

Development of product profile for target-oriented accelerated breeding in chickpea (*Cicer arietinum* L.)

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Abstract

Chickpea (*Cicer arietinum* L.) breeding in India, dating back to more than a century, has significantly contributed to increased production by developing many high-yielding, stress resistant varieties with desirable seed quality and market preference traits. However, with ever increasing pressure for further improvement, there is a need to make the varietal development process consumer-oriented, catering to present and near future demands. The development of new varieties has direct implications on national chickpea yields, affecting the food/feed availability and nutritional balance from the consumer's perspective and livelihood security from the growers' perspective. The national breeding programs need to formally align by prioritizing the essential and desirable traits, benchmarks and a product development timeline. In the present study we have described the development of a Product Profile of chickpeas suitable for different crop ecologies in the country, which may act as a blueprint for varietal development. There is a need to strike a balance between present and near future demands and therefore, the pros and cons of such an approach and their possible implications on future chickpea breeding was also discussed.

Kywords: Chickpea, Product profile, Breeding, Genetic gain.

Introduction

Chickpea (*Cicer arietinum* L.) has played a major role in realizing the Pulses Revolution in India, making the country nearly self-sufficient in Pulses (Dixit et al. 2020; Singh et al. 2020). There is a quantum jump of 5.79 million tonnes in chickpea production during 2021-22 (13.12 million tonnes) compared to 2014-15 (7.33 m t). This is accompanied with more than 28% increase in chickpea productivity during 2021-22 (1142 kg/ha) as compared to productivity in 2014-15 (889 kg/ha) (Anonymous 2022). The pillar stone to this improvement has been robust chickpea breeding in India which has fairly successful exploited key traits viz., enhanced yield, resistance to biotic and abiotic stresses, altered phenology and plant types, addition of consumer preferred traits etc (Singh et al. 2017; Sahu et al. 2020; Singh et al. 2021; Nunavath et al. 2022).

Chickpea breeding has evolved over years from mere pure line selection from existing heterogeneous land races followed by conventional hybridization among diverse parents and recently to the application of modern biotechnological tools to accelerate genetic gain. Many high yielding, disease-resistant varieties were developed through various breeding methods, which led to the stability in chickpea production with about 20% annual growth rate in productivity. As on today, more than 250 varieties for various states and agro-ecological conditions have been recommended for cultivation at national or state level (Dixit 2021a).

However, with ever-increasing challenges posed by changing climate, disease and pest scenarios, market preference *etc*, there is utmost need to increase the efficiency of breeding by utilizing modern genomics and breeding tools, reduced breeding cycle, better breeding data management system for pedigree, breeding nursery and trial data. In order to standardize chickpea breeding

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efforts across the country, there is a need to develop a blueprint for variety development (Dixit et al. 2019). This should be market-driven for end user-based product development through the utilization of cross-functional knowledge of market, breeding, crop management, socio-economics, farmers and consumers expertise (EIB 2018). Keeping this objective in mind, the All India Coordinated Research Project on Chickpea in collaboration with the Excellence in Breeding (EiB) platform, has made an effort to develop product profiles of *desi* and *kabuli* chickpea varieties for different chickpea growing zones of the country.

Materials and methods

Components of product profile

The Product profile provides necessary characters in a variety needed to replace old variety. This includes basic traits/USP's, value-added traits, benchmark lines, level of increase and time schedule for improvement. The basic traits are the must-have traits in a variety, including yield, stress resistance, seed quality traits. The value-added traits are additional traits that give the new variety an edge over existing ones in terms of higher yield, increased profit, etc.

Selection of base varieties

The improvement in a trait of the new variety is estimated over that in the most popular variety/benchmark variety which covers the maximum area under cultivation. This may be an old variety that is still popular among the farmers.

Selection of traits, benchmark and timeline for varietal development

The Excellence in Breeding (EiB) is one of CGIAR's Global Integrating Programs which coordinates the efforts of leaders from CGIAR and national agricultural research systems (NARS), funders and private sector partners for developing more resilient, productive and nutritious crop varieties and livestock breeds by increasing the rates of genetic gain and variety turnover (https://excellenceinbreeding.org/). A thorough discussion was made among the AICRP on Chickpea and EiB team for streamlining the basic traits/USP's, value added traits, benchmark lines, level of increase and time schedule for improvement. This was vetted with different researchers, processors, growers and consumers from AICRP centres situated in different zone *viz*., North West Plain Zone, North East Plain Zone, West Central Zone, East Central Zone and South Zone. The framework was then discussed with EiB team and other stakeholders and finalized. The level of increase expected in the trait in the improved variety is fixed based on the minimum values ascertained in the nationally coordinated yield evaluation trials. A realistic timeline of 5-8 years is fixed for the development of variety.

Results and discussion

Chickpea breeding in India, like other major crops follows an organized structure involving a number of agricultural universities and research institutes developing breeding material that is tested nationally through AICRP on Chickpea. These centers are well supported by ICAR Institutes like ICAR-IIPR, ICAR-IARI *etc*. and international institutions like ICRISAT and ICARDA in terms of sharing of segregating and advanced generation breeding material and extending genotyping and phenotyping facilities. This arrangement enables breeders to initially evaluate their material in different agro-climatic zones and identify superior lines suitable in a particular ecology for release as a variety. The variety is then inducted into the seed chain for producing quality seed and side by side popularized through on-farm demonstrations among the farmers. This structured but somewhat rigid approach aims at the development of an ideal variety which is then handed over to farmers without their direct involvement. The process has been fairly successful in developing more than 250 chickpea varieties suitable for cultivation in more than 25 states in the country. However, all the newly released varieties do not gain equal popularity among the farmers. Despite having significant yield superiority, these cannot replace old varieties that are still popular among the farmers due to some desirable traits. This is evident from the formal seed indent for breeder seed of variety received from different states where many old mega varieties still exist across different crops, including cereals (PBW 343, HD 2967and HD 3086' in wheat; Pusa Basmati 1121, Pusa Basmati 1509 and Pusa Basmati 1718 variety of rice), pulses (JG 11, JAKI 9218, JG 16, Vijay in Chickpea); oilseeds (Pusa Mustard 25 and Pusa Mustard 30), sugarcane (Co-0238/Karan, Co-86032/Nayana), potato (Kufri Pukhraj) etc. (Singh et al. 2019; Kumar and Pal 2020; Dixit 2021b). This necessitates the inclusion of end user in the decision-making process of varietal development and also signifies the importance of old but popular varieties with major market shares having market preferences traits.

Key traits for product profile development

The coordinated research efforts for Chickpea breeding in India has been based on five agro-ecological zones namely North West Plain Zone (NWPZ), Norh East Plain Zone (NEPZ), West Central Zone, East Central Zone and South Zone (Chaturvedi et al., 2014). Each zone is characterized by distinct soil type, weather pattern, cropping system, crop duration etc. Hence, a need was felt to develop zone specific product profile. A number of traits *viz,* yield and yield component traits (seed yield/plant, seed/plant, pods/plant, seeds/pod, filled pods (%) etc), plant traits (Leaf color, growth habit, plant height,no. of leaflets/leaf, leaflet length etc) phenological traits (days to 50% flowering, days to maturity), seed quality traits (100 seed weight, seed shape, seed color), biotic and abiotic stress resistane traits and nutritional components (Protein content, Fe content, Zn content etc) were considered. After thoroughly brainstorming with the stakeholders from each zone, it was decided to include crop

duration, biotic and abiotic stress resistance, seed size and nutritional quality as basic traits and yield and amenability to mechanical harvesting as the varieties' value-added traits/ unique selling propositions.

North West Plain Zone

In NPWZ, the producers (Farmers) required high yield, disease resistant varieties with semi-erect or erect growth habit, non-lodging having brownish yellow (golden) color medium size desi varieties. The processors (Millers) demanded medium-seeded varieties (15 to 20 g/100 seed) with better dal recovery and uniform seed size. The consumers desired brown to light brown seeded varieties with uniform medium-size seeds with good culinary properties. The taste of medium seeded varieties was preferred, while bold seeds for green pods were required.

North East Plain Zone

In NEPZ, the producers (Farmers) required high-yielding varieties with multiple disease resistance. The processors (Millers) demanded varieties with good dal recovery and of medium seed size. The consumers desired varieties with yellow brown seed color.

West Central Zone

In WCZ, the producers (Farmers) required high-yielding yellow-colored *desi* varieties with semi-spreading growth, early maturity and resistance to wilt complex, tolerant to pod borer, drought tolerant. The processors (Millers) demanded varieties with good dal recovery and of medium seed size. The consumers desired varieties with yellow brown seed colour. The consumers desired varieties with yellowish brown seed color, bold seed size, and resistant to store grain pest *viz* bruchid. The kabuli varieties should have white to beige color with two distinct seed size categories namely kabuli (35-40 g/100 seed) and extra-large seeded kabuli (>40 g/100 seed). These should have tolerance of abiotic (frost and drought) and biotic stress (Fusarium wilt and dry root rot).

East Central Zone

In ECZ, the producers (Farmers required high yielding desi varieties with multiple disease resistance with profuse branching. The processors (Millers) demanded varieties with uniform seed size/shape. The consumers desired golden or light brown seeded varieties with uniform seed shape/size.

South Zone

In SZ, the producers (Farmers) required high yield, disease-resistant desi varieties with semi-erect or erect growth habit, and profuse flowering. The processors (Millers) demanded varieties with >75% dal recovery. The consumers desired golden or light brown seeded varieties with uniform seed shape/size. The *kabuli* varieties should have white to beige color with two distinct seed size categories namely *kabuli* (35-40 g/100 seed) and extra-large seeded *kabuli* (>40 g/100 seed). These should have tolerance for abiotic (heat and drought) and biotic stress (Fusarium wilt and dry root rot).

Product profile of Desi chickpea varieties

Based on the feedback received from different stakeholders, product profiles were made for *Desi* chickpea varieties for each zone.

Commercial product of desi chickpea to be replaced

The first step in product profile development is identifying the most popular variety of the region, which acts as a benchmark for new varieties. Based on yield potential, consumer preference and demand, a recently released high yielding chickpea variety was identified for each zone (Table 1). These included GNG 2171 for NWPZ, GNG 2207 for NEPZ, Phule G 0405 for WCZ, IPC 2006-77 for ECZ and Super Annigeri-1 for SZ.

Basic traits/unique selling Prepositions in the product profile of desi chickpea

The basic traits to be included in the product profile were based on stakeholders' consultation (Table 2). For NWPZ, the desi chickpea product profile included a crop growing window of 130 to 150 days. Among biotic stress, Ascochyta blight, *Fusarium* wilt and botrytis grey mold, drought and cold tolerance among abiotic stress were included as major breeding objectives. The variety should also have medium bold seed size (16–20 g/100 seed) preferably having higher protein, iron and/or zinc content. For NEPZ, the desi chickpea variety should have a maturity duration of 120 to 130 days having resistance against *Fusarium* wilt, BGM and collar rot. The variety should also possess terminal drought and high-temperature tolerance. It should preferably have seed size varying from 18-22 g with higher seed protein and iron/ zinc content. For WCZ, the desi chickpea variety should have a maturity duration of 105 to 110 days, having resistance against fusarium wilt, dry root rot and collar rot/stunt. The variety should also possess drought and high temperature tolerance. For ECZ, the desi chickpea variety should have a 120 to 130 days maturity duration with resistance against *Fusarium* wilt, dry root rot and collar rot. The variety should also possess drought and frost tolerance. For SZ, the desi chickpea variety should have a maturity duration of 105-110 days having resistance against fusarium wilt and dry root

Table 1. Name of commercial product of *desi* chickpea to be replaced

Agro-ecology zone	Name of commercial product to be replaced	Year of release
North West Plain Zone	GNG 2171	2017
North East Plain Zone	GNG 2207	2019
West Central Zone	Phule G 0405	2018
East Central Zone	IPC 2006-77	2019
South Zone	Super Annigeri 1	2019

Table 2. Basic traits/ unique selling prepositions in the product profile of desi chickpea

Agro-ecology zone	Basic traits				
	Maturity	Biotic stress resistance*	Abiotic stress resistance	100 seed weight (HSW)	Nutritional quality#
North West Plain Zone	130-150 days	AB, FW, BGM	Drought, cold tolerance	16-20 g	High Protein, Fe, Zn
North East Plain Zone	120-130 days	FW, BGM, CR	Terminal drought, high temperature	18-22 g	High Protein, Fe, Zn
West Central Zone	105-110 days	FW, DRR, CR/Stunt	Drought, high temperature	18-22 g	High Protein, Fe, Zn
East Central Zone	120-130 days	FW, DRR, CR	Drought, frost tolerance	18-22 g	High Protein, Fe, Zn
South Zone	105-110 days	FW, DRR	Drought, high temperature	18-22 g	High Protein, Fe, Zn

AB= *Ascochyt*a blight, FW= *Fusarium* wilt, BGM = Botrytis Gray Mold, CR = Collar Rot, DRR = Dry root rot

#High Protein: >25g/100g seed; High Fe: >60ppm in seed; Zn: >40ppm in seed

Table 3. Value added traits in the product profile of desi chickpea

Agro-ecology zone	Value added trait 1 (High seed yield)		Value added trait 2 (Mechanical harvesting)	
	Benchmark line or variety	Your trait compared to the benchmark	Benchmark line or variety	Your trait compared to the benchmark
North West Plain Zone	GNG 2171	≥ benchmark by 10%	HC 5	≥ benchmark by 5%
North East Plain Zone	GNG 2207	≥ benchmark by 10%	HC 5	≥ benchmark by 5%
West Central Zone	Phule G 0405	≥ benchmark by 10%	Phule G 08108	≥ benchmark by 5%
East Central Zone	IPC 2006-77	≥ benchmark by 10%	Phule G 08108	≥ benchmark by 5%
South Zone	Super Annigeri 1	≥ benchmark by 10%	NBeG 47	≥ benchmark by 5%

rot. The variety should also possess drought and high temperature tolerance. The preferable seed size for central and south zone is 18-22 g/100 seed with higher seed protein and iron/zinc content.

Value added trait and timeline for product development

The value-added traits included higher yield and amenability to mechanical harvesting. The benchmark for yield was set as more than 10% yield over the commercial variety for each zone (Table 3).The benchmark for amenability to machine harvesting was set as more than 5% yield over the machine harvestable variety for each zone. The benchmark varieties included HC 5 for northern zones (NWPZ and NEPZ), Phule G 08108 for central zone (WCZ and ECZ) and NBeG 47 for south zone. All these tall varieties have erect plant growth habit and set pods above 25 cm from the ground level.

Product profile of Kabuli chickpea varieties

Based on the feedback received from different stakeholders, product profiles were made for *Kabuli* chickpea varieties for each zone.

Commercial product of kabuli chickpea to be replaced

The first step in product profile development is identifying the most popular variety of the region, which acts as a benchmark for new varieties. Based on yield potential, consumer preference and demand, a popular high yielding chickpea variety was identified for each zone (Table 4). These included PKV Kabuli 2 (KAK2) for WCZ and NBeG 119 for SZ among *kabuli* type and PKV 4/Kripa for WCZ and MNK 1 for SZ among extra-large seeded *kabuli* type.

Basic traits/unique selling prepositions in the product profile of Kabuli chickpea

For WCZ, the *kabuli* chickpea variety should have a maturity duration of 90 to 115 days having resistance against diseases like fusarium wilt, dry root rot and collar rot (Table 5). The variety should also possess frost and drought tolerance. For SZ, the *kabuli* chickpea variety should have a maturity duration of 90 to 110 days having resistance against fusarium wilt and dry root rot. The variety should also possess drought and high temperature tolerance. The preferable seed size of *kabuli* type for central and south zone is 35-40 g/100 seed with white to beige seed color.

The extra-large seeded *kabuli* (>40 g per 100 seed weight) should have a maturity duration of 90 to 115 days and resistance against *Fusarium* wilt, dry root rot and collar rot. The variety should also possess frost and drought tolerance. For SZ, the extra-large seeded *kabuli* variety should have a maturity duration of 105 to 110 days having resistance against fusarium wilt and dry root rot. The

Table 4. Name of commercial product of kabuli chickpea to be replaced

Kabuli Type	Agro-ecology zone	Name of commercial product to be replaced	Year of Release
Kabuli (35-40g/100 seed)	West Central Zone	PKV Kabuli 2 (KAK2)	1999
	South Zone	NBeG 119	2016
Extra-large seeded kabuli (>40g/100 seed)	West Central Zone	PKV 4/Kripa	2009
	South Zone	MNK 1	2011

Table 5. Basic traits/unique selling prepositions in product profile of kabuli **Chickpea**

Kabuli type	Agro-ecology zone	Basic Traits				
		Seed ize(HSW)	Maturity	Biotic stress resistance	Abiotic stress resistance	Seed quality
Kabuli	West Central Zone	35-40 g	90-115 days	FW, DRR/Collar rot	Frost, Drought tolerance	White to beige seed
	South Zone	35-40 g	90 - 100 days	FW, DRR	Heat, drought tolerance	White to beige seed
Extra-large seeded kabuli	West Central Zone	More than 40g	90-115 days	FW, DRR/Collar rot	Frost, Drought tolerance	White to beige seed
	South Zone	More than 40g	105-110 days	FW, DRR	Heat, drought tolerance	White to beige seed

FW = *Fusarium* wilt, DRR = Dry root rot, CR = Collar rot

Table 6. Value added traits in the product profile of kabuli chickpea

Kabuli Type	Agro-ecology zone	Value added trait 1 (High seed yield)		Value added trait 2 (Mechanical harvesting)	
		Benchmark line or variety	Your trait compared to the benchmark	Benchmark line or variety	Your trait compared to the benchmark
Kabuli	West Central Zone	PKV Kabuli 2 (KAK2)	≥ benchmark by 10%	PKV Kabuli 2 (KAK2)	≥ benchmark by 5%
	South Zone	NBeG 119	≥ benchmark by 10%	NBeG 119	≥ benchmark by 5%
Extra-large seeded kabuli	West Central Zone	PKV 4/Kripa	≥ benchmark by 10%	PKV 4/Kripa	≥ benchmark by 5%
	South Zone	MNK 1	≥ benchmark by 10%	MNK 1	≥ benchmark by 5%

variety should also possess drought and high temperature tolerance. The preferable seed size of *kabuli* type for central and south zone is more than 40 g/100 seed with white to beige seed colour.

Value added trait and timeline for product development

The value-added traits included higher yield and amenability to mechanical harvesting with more than 10% yield threshold over the commercial variety for each zone (Table 6). The benchmark for amenability to machine harvesting was set as more than 5% yield over the machine harvestable variety for each zone. The benchmark varieties PKV Kabuli 2 for WCZ and NBeG 119 for SZ among kabuli types and PKV4/Kripa for WCZ and MNK 1 for SZ among extra-large seeded kabuli types.

This product profile is based on assumption of present and near-term demand of the consumers (Sumberg et al. 2012; 2013) and can be used as a template for breeding future crop varieties for a particular niche in farming systems or consumer demand (Sumberg and Reece 2004). However, caution should be exercised on its thorough implementation at all the breeding centres. The concept of product profile has been ritually followed by many product-based companies based on prediction of future demand. Some of these succeed while others failed to find a market. Development of new varieties has direct implications on national yields of crops which in turn affects the food, feed and nutritional balance from consumers perspective and ecosystem sustainability and livelihood security from growers' perspective. Pulses in general are cultivated by resource poor farmers on marginal lands and provide much needed fillip to soil nutrient balance. Any rigid approach towards market driven breeding has to be screened through test of sustainability of the ecosystem and have different breeding elements in anticipation of other growing conditions/policy shifts etc (Miller and Poli 2010). A typical example would be the success of Chickpea in Andhra Pradesh in South India after its major area in Northern India shifted to irrigated cereals.Availability of suitable variety, sudden decline in cultivation of preferred crop of Andhra Pradesh, demand from the farmers for alternate crop and concerted seed production efforts along with favorable policy decisions ushered a silent chickpea revolution in the

state (Dominic et al. 2021). This would not have been possible if chickpea breeding was totally focused on research priorities and demand of the northern India. Thus, there is a need to strike balance between present and near future demands and anticipating the future demands that may lead to new developmental pathways and technological trajectories.

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Authors' contribution

Conceptualization of research (GPD, AKS, CB); Designing of the experiments (AKS, GPD); Execution of field/lab experiments and data collection (AKS, RS); Analysis of data and interpretation (AKS, GPD, CB); Preparation of the manuscript (AKS, GPD).

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