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# Breeding Novel Genotypes in Chickpea and Lentil

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**ABSTRACT**

Among cool season pulses, chickpea and lentil account for over 74% and 79%, respectively of the total area and production under *Rabi* pulses in India. The climate change has resulted in contraction of cool season duration, and as a result, terminal heat stress and root diseases complex are constraining the productivity of both chickpea and lentil. This has necessitated breeding novel genotypes with unique adaptive features to combat the adverse impacts of climate change. Two crosses (BGD 9971 × IPCK 2002-29 and BGD 9971 × JG 16) of chickpea were advanced to succeeding generations commencing from 2014-15. In $F_1$ generation, one $F_1$ (BGD 9971 × IPCK 2002-29) showed only partial dominance of non-determinate (NDT) growth habit (of IPCK 2002-29) over the determinate (DT) habit (of BGD 9971). However, the second cross (BGD 9971 × JG 16) indicated complete dominance of NDT (JG 16) over the DT type (BG 9971); the $F_2$ generation showed a 15 (NDT):1 (DT) ratio, showing duplicate gene action for growth habit in chickpea. The same was confirmed in the randomly selected $F_3$ progenies also. During 2018-19, a total of 4 DT $F_6$ progenies derived from the cross (BGD 9971 × IPCK 2002-29) were grown and assessed in preliminary trial for yield and other attributes. Based on their performance over the check (IPCK 2002-29), two superior lines, viz. RCECK 17-2 and RCECK 17-4, were selected for further evaluation. The 'RCECK 19-4' significantly outyielded (1852 kg/ha) the check 'IPCK 2002-29' (1513 kg/ha). In lentil, a segregating population derived from a cross (ILWL 118 × DPL 58) was also advanced, and 16 single plant selections (SPS) were performed based on biomass, earliness and no. of pods. Further selections in succeeding generations resulted in the identification of a super early genotype 'RCEL 19-1' in the year 2019-20. Besides super earliness, this genotype when evaluated in wilt-sick nursery showed greater mortality than the susceptible check 'Seohore 74-3', making it a suitable susceptible check for assessing wilt reaction of test genotypes in the pathological trials. These two novel genotypes, *viz*. 'RCECK 17-4' (chickpea) and 'RCEL 19-1' (lentil), hold promise to be registered as useful genetic stocks for further utilization in breeding programmes.

**Keywords:** Chickpea, growth habit, duplicate gene action, lentil, super early type, genetic stocks, RCECK 17-4, RCEL 19-1

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## INTRODUCTION

Food grain
Cool season pulses especially chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik.) are an importance source of protein for vegetarians the world over including India. As per FAO statistics (2020), worldwide these two crops occupy more than 19.84 million ha (Mha) area, producing more than 21.5 million tons (MTs) of seed yield. India, which is a major pulse producing country in the world, alone accounts for more than 57% and 62% of the world's total area and production, respectively (DES, 2021). Although good progress in overall production of both the pulses has been registered during the last five years (2016-17 to 2020-21), year to year fluctuation (instability) in the productivity has been a matter of great concern for researchers and policy planners alike.

Climate change impacts are evident in each crop production environment. Empirical observations indicate that "cool season" period has contracted by one-two weeks during *Rabi* season in both north-east and north-west plains of India. It is well documented that global warming-induced high temperatures have changed the pattern of rainfall as well as distribution, leading to excess and deficient temporal moisture stresses (Kumar *et al.*, 2019). Such abiotic stresses are expected to pose serious threats to pulses productivity in the near future due to adverse effects on biomass production, maturity period, days to flowering, rate of fertilization and seed formation inside the pods. Moreover, increasing effects of climate change are also reflected in terms of disease stresses, and have become the major impediments to both chickpea and lentil production (Choudhary *et al.*, 2013). In both the crops, the intensity of root diseases especially Fusarium wilt has increased. Although there are well established and identified physiological races/strains in both the crops (Choudhary *et al.*, 2013; Choudhary and Kumar, 2016), the possibility of new pathotypes imposing additional ceiling effects on the genetic progress cannot be ignored (Choudhary *et al.*, 2022).

Under changing climate situation, it is imperative to adopt mitigation and adaptation strategies for sustaining the production and productivity of pulses. However, pulse farmers in general are resource poor especially in South Asia

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and Africa, and can hardly afford adoption of mitigation strategies. This calls for resolving the issues of climate change primarily through adaptation strategies (Kumar *et al.*, 2019). Chickpea germplasm abounds in non-determinate (NDT) accessions; such a growth habit under favourable conditions of soil moisture and temperature leads to excessive vegetative growth, which in turn acts as the competitive sink for developing pods, eventually resulting in poor pod formation. However, genes for determinacy have been identified in a newly developed genotype 'BGD 9971'. This has paved the way to initiate breeding for modifying adaptation of chickpea to the changing situation (Hegde, 2011). The contraction of cool period due to increasing global warming is likely to have greatest impact on biomass production of lentil. Therefore, early vigour, early flowering and early maturity has become indispensable in lentil breeding programme. Climate change has also impacted intensity of Fusarium wilt in lentil. However, physiological races and differential sets are not so well established in lentil (Choudhary *et al.*, 2013).

Depending on the seed size and color, chickpea is classified as *Kabuli* type (macrosperma) and *Desi* type (microsperma). Whereas the former bears more number of primary branches, the latter bears more number of pods/plant and seeds/pod (Choudhary *et al.*, 2022). Because of these reasons, breeders have more often resorted to *Kabuli-Desi* introgressive hybridization. It is a proven fact that field screening for wilt resistance is not as precise as the laboratory screening. However, field screening in lentil is still a major activity in All India Coordinated Research programme (AICRP). In the north-east plains, 'Sehore 74-3' is used as a susceptible check in wilt-sick nursery. However, percentage mortality is not so high compared to the susceptible check (JG 62) used in chickpea. Keeping these facts in view, we undertook a breeding programme to develop novel genotypes in chickpea and lentil.

## MATERIALS AND METHODS

The base materials and their salient features used in the present study are given in the Table 1. Two crosses (BGD 9971 × IPCK 2002-29 and BGD 9971 × JG 16) in chickpea were advanced to the second filial ($F_2$) generation during 2014-15. The $F_1$ and $F_2$ generations were grown along with the parents during the next cropping season to assess the breeding behavior of $F_1$'s and segregating pattern in $F_2$ generation. In $F_2$ generation, all plants were separately harvested, threshed and packed to assess their individual breeding behavior in the $F_3$ generation. Only randomly selected $F_3$ progenies were advanced in the next generation. In $F_3$ progenies derived from the cross involving *Kabuli* chickpea (BGD 9971 × IPCK 2002-29), a total of 16 determinate *Kabuli* type plants were selected, and advanced further in succeeding generations along with 'IPCK 2002-29' as the check. This led to selection of four determinate genotypes of Kabuli chickpea (RCECK 17-1, RCECK 17-2, RCECK 17-3 and RCECK 17-4) during 2018-19. These genotypes were assessed in preliminary yield trial (2019-20); the promising two genotypes, *viz*. RCECK 17-2 and RCECK 17-4, yielding above par with 'IPCK 2002-29' were selected further for their evaluation in randomized complete block design (RCBD) in 2020-21 and 2021-22. Based on the performance and desirable agronomic attributes, 'RCECK 17-4' was selected for multiplication and utilization.

**Table 1:** Description of the materials used in the present study

| Crop | Genotype and their pedigree | Salient features |
|---|---|---|
| Chickpea | IPCK 2002-29 (Shubhra) | A released variety of *Kabuli* chickpea for central zone; erect with light green foliage, white and large seeds (33g/100 seeds) |
| | BG 9971 (IC635055) | An advance breeding line of *Desi* chickpea with determinate growth habit. Plants are bushy, compact and dwarf in stature. The growth of the branches is typically arrested by the absence of terminal buds, and a single pod may contain 1-4 seeds |
| | JG 16 (SAKI 9516) | A released variety of *Desi* chickpea for central zone; semi-spreading plant type with profuse branching, dark green foliage with light brown and medium size seeds (19g/100 seeds) |
| Lentil | ILWL 118 | A wild accession (*Lens culinaris* ssp. *orientalis*) having green foliage and resistance to rust disease; late maturity (flowering starts at 80-85 days after sowing) with small seeds and red cotyledon |
| | DPL 58 | A breeding line with green foliage and wilt resistance; seeds are large (>3g/100 seeds) with yellow cotyledons |

*Source :* PC Report (2018-19), AICRP on Chickpea; Hegde (2011); Kumar and Gupta (2019)

A segregating population from a cross (ILL 118 × DPL 58) was also grown during the Rabi season 2014-15, and a total of 10 single plant selections was performed and kept for further multiplication and purification in the succeeding generations. Five extra early spreading and five extra early tall and compact types, maturing in less than 90 days were selected during 2017-18. However, only five super early compact types, *viz.* RCEL 19-1, RCEL 19-2, RCEL 19-3, RCEL 19-4 and RCEL 19-5, were selected for further assessment during 2018-19. During 2019-20, 'RCEL 19-1' was selected as the earliest one. However, it was found to be highly susceptible to root diseases, and therefore, it was put to pathological trial in the wilt sick nursery at Tirhut College of Agriculture (TCA), Dholi for succeeding two years (2020-21 and 2021-22). The segregation data were subjected to the standard chi-square test as per Strickberger (1996). For computing mean and standard deviation, we used OPSTAT that is available online. The segregating generations during 2014-2016 were advanced at Research Centre for Makhana, Darbhanga, and the succeeding generations and yield trials were conducted at ICAR Research Complex for Eastern Region, Patna during 2016-2022.

## RESULTS AND DISCUSSION

The details of segregation pattern for growth habit in the two crosses (BGD 9971 × IPCK 2002-29 and BGD 9971 × JG 16) are given in Table 2. The $F_1$, $F_2$ and $F_3$ (BGD 9971 × IPCK 2002-29

**Table 2:** Segregation pattern for non-determinate vs. determinate growth habit in $F_2$ and $F_3$ generations from two crosses in chickpea

| Generation | NDT plants (no.) | DT plants (no.) | Expected ratio | Probability of $\chi^2$ value |
|---|---|---|---|---|
| BGD 9971 × IPCK 2002-29 | | | | |
| $F_1$ | 30 | 0 | - | - |
| $F_2$ | 203 | 15 | 15:1 | 0.147 (P=0.75-0.50) |
| $F_3$ Progeny 1 | 287 | 21 | 15:1 | 0.169 (P=0.75-0.50) |
| Progeny 2 | 189 | 15 | 15:1 | 0.423 (P=0.75-0.50) |
| Progeny 3 | 176 | 48 | 3:1 | 1.522 (P=0.25-0.10) |
| BGD 9971 × JG 16 | | | | |
| $F_1$ | 35 | 0 | - | - |
| $F_2$ | 128 | 12 | 15:1 | 1.287 (P=0.50-0.25) |
| $F_3$ Progeny 1 | 308 | 24 | 15:1 | 0.543 (P=0.50-0.25) |
| Progeny 2 | 151 | 40 | 3:1 | 1.675 (P=0.25-0.10) |
| Progeny 3 | 116 | 31 | 3:1 | 1.198 (P=0.25-0.10) |

and BGD 9971 × JG 16) generations indicated partial to complete dominance of NDT (IPCK 2002-29/JG 16) over the DT (BGD 9971) type. $F_2$ generation showed a 15 (NDT):1 (DT) ratio. In $F_2$ generation, the two populations (BGD 9971 × IPCK 2002-29 and BGD 9971 × JG 16) segregated into NDT and DT type plants (Table 2), fitting well to 15 NDT: 1 DT ratio (P=0.75-0.25), indicating that the expression of determinate growth habit in 'BG 9971' was controlled by two recessive genes (loci). The NDT growth habit in 'IPCK 2002-29' and 'JG 16' appeared to be governed by two duplicate dominant genes. Randomly selected 3 $F_3$ progenies (descended from individual $F_2$ plants) from each cross (BGD 9971 × IPCK 2002-29 and BGD 9971 × JG 16) were also assessed for segregation pattern into NDT vs. DT plants. Two $F_3$ progenies derived from BGD 9971 × IPCK 2002-29 and one F3 progeny from BGD 9971 × JG 16 again confirmed a 15: 1 ratio of growth habit (NDT/DT; P = 0.75 - 0.25). One $F_3$ progeny from BGD 9971 × IPCK 2002-29 and two $F_3$ progeny from BGD 9971 × JG 16 showed a 3:1 ratio of growth habit (NDT/DT; P=0.25-0.10). This was not unexpected as these three progenies could be segregating at a single locus (only one of the duplicate genes). While studying the genetics of growth habit, Hegde (2011) also reported that the determinate growth habit in 'BGD 9971' was governed by two recessive genes ($dt_1dt_1dt_2dt_2$).

Encouraged with the typical architecture (bushy, compact and dwarf stature), it was decided to advance and purify good looking four DT types descended from the cross that involved a *Kabuli* chickpea variety 'IPCK 2002-29' in succeeding generations. Based on the performance of individual lines (data not presented), the best one 'RCECK 17-4' was selected for comparative assessment with the check 'IPCK 2002-29'. The data is given in Table 3. It is evident that the determinate genotype 'RCECK 17-4' outperformed the check 'IPCK 2002-29' during both the years, and showed a mean yield advantage by over 22% over the check. The novel *Kabuli* genotype 'RCECK 17-4' is short in stature (45.1 cm), and has significantly more number of primary and secondary branches, and higher seed yield/plant than the check parent (IPCK 2002-29). This genotype (RCECK 17-4) showed comparable biological yield and pods/plant. Although data on seeds/pod and plant density were not recorded, these two traits might have played an important role in imparting yield superiority to this genotype.

In lentil, 'RCEL 19-1' was selected as the best super early compact type based on its comparative assessment over 'Ranjan' (a released variety of lentil) for early vigour, days to flowering (41 days), maturity period (< 90 days) and yield superiority in preliminary yield trial (data not presented) during 2019-20. Although the genotype looked promising as a source of earliness for its potential use in future breeding programme, it appeared highly susceptible to root diseases in field condition. Therefore, it was decided to observe its performance in the wilt-sick nursery at TCA, Dholi (Muzaffarpur). The results of the pathological trial in wilt sick plot are given in Table 4. A perusal to the Table 4 indicates that during both the years (2020-21 & 2021-22), the percentage wilting in 'RCEL 19-1' was substantially higher than the susceptible check 'Seohore 74-3'. The percentage wilting on weighted mean basis were 84.28 and 56.42 for 'RCEL 19-1' and 'Seohore 74-3', respectively.

Datta *et al.* (2009) performed variability analysis comprising 24 isolates of *Fusarium oxysporum* f. sp. *lentis* (FOL) collected from north eastern Indo-Gangetic plains using 40 RAPD and 12 SSR primer pairs; the analysis could reveal two sub-populations. In another study, Belabid *et al.* (2004) found that FOL isolates differed in their aggressiveness on susceptible lines. The susceptible check 'Seohore 74-3' belongs to the central zone; however, it is used as the susceptible check in the north-east plains. It appears that aggressiveness of north-east FOL strains/isolates may not be so strong against 'Seohore 74-3' as compared to 'RCEL 19-1'. This calls for revisiting the use of 'Seohore 74-3' as the susceptible check in the wilt sick plot, and this makes 'RCEL 19-1' an ideal candidate to be used as

**Table 3:** Performance of RCECK 17-4 vis-à-vis IPCK 2002-29

| Characters | 2020-21 | | 2021-22 | | Mean over two years | |
|---|---|---|---|---|---|---|
| | IPCK 2002-29 | RCECK 17-4 | IPCK 2002-29 | RCECK 17-4 | IPCK 2002-29 | RCECK 17-4 |
| Yield (kg/ha) | 1252 (122) | 1671 (202) | 1774 (260) | 2032 (301) | 1513 (369) | 1852 (255) |
| 100 seed wt (g) | 32.44 (1.44) | 27.96 (0.64) | 30.29 (1.21) | 27.50 (0.59) | 31.37 (1.52) | 27.73 (0.33) |
| Plant height (cm) | 66.20 (4.76) | 42.40 (3.04) | 68.40 (3.21) | 47.80 (3.63) | 67.3 (1.55) | 45.1 (3.81) |
| Pods/plant (no.) | 95.60 (12.89) | 100 (24.46) | 97.40 (7.57) | 90.60 (4.39) | 96.5 (1.28) | 95.3 (6.64) |
| Primary branches (no.) | NA | NA | 1.80 (0.44) | 2.80 (0.83) | 1.80 (0.44) | 2.80 (0.83) |
| Biological yield/plant (g) | 59.6 (5.72) | 77.6 (17.85) | 80.20 (3.89) | 64.20 (8.61) | 69.9 (14.56) | 70.9 (9.47) |
| Seed yield/plant (g) | 28.8 (3.90) | 39.4 (11.56) | 27.20 (3.83) | 28.20 (5.54) | 28 (1.13) | 33.8 (7.91) |
| Secondary branches/plant (no.) | NA | NA | 19.00 (4.47) | 25.40 (3.04) | 19.00 (4.47) | 25.40 (3.04) |

Figures in parentheses indicate standard deviation of the mean

**Table 4:** Performance of 'RCEL 19-1' in wilt-sick nursery at Tirhut College of Agriculture, Dholi (Muzaffarpur), Bihar

| Entries | Observation year (2020-21) | | | | % wilt over replication |
|---|---|---|---|---|---|
| | R1 | | R2 | | |
| | Emergence | No. of wilted plants | Emergence | No. of wilted plants | |
| RCEL 19-1 | 40 | 25 | 40.00 | 35 | 75.00 |
| S Ch (Sehore 74-3) | 40 | 25 | 40.00 | 22 | 58.75 |
| | Observation year (2021-22) | | | | |
| RCEL 19-1 | 30 | 28 | 30 | 30 | 96.67 |
| S Ch (Sehore 74-3) | 30 | 14 | 30 | 18 | 53.33 |
| Total over two years (2020-21 & 2021-22; % wilt on weighted mean basis) | | | | | |
| RCEL 19-1 | 70 | 53 | 70 | 65 | 84.28 |
| S Ch (Sehore 74-3) | 70 | 39 | 70 | 40 | 56.42 |

S Ch: susceptible check

susceptible check in field screening of lentil genotypes for wilt resistance in north-east plains.

## CONCLUSION

Climate change has changed the weather pattern including rainfall pattern. This has intensified the occurrence of both abiotic and biotic stresses including emergence of new pests (biotypes) and pathogens (physiological races). Our breeding programmes in cool season pulses aimed at addressing these issues through development of novel genotypes. In the present study, we successfully demonstrated that *duplicate* gene action accounts for inheritance of growth habit in chickpea. Moreover, we successfully utilized determinate genes ($dt_1dt_1dt_2dt_2$) from 'BG 9971', and incorporated into 'RCECK 17-4'. This changed not only the growth habit, but also improved the morphology and seed yield of the novel *Kabuli* chickpea genotype. We also successfully isolated a super early *transgressive* genotype 'RCEL 19-1' from a cross (ILL 118 × DPL 58) that involved a wild accession. This genotype showed highly susceptible reaction even over the susceptible check 'Seohore 74-3' in the wilt sick plot at TCA, Dholi (Muzaffarpur). These two novel genotypes, 'RCECK 17-4' and 'RCEL 19-1' need to be registered with National Bureau of Plant Genetic Resources (NBPGR), New Delhi as the unique genetic stocks/donors for further utilization in the national and international breeding programmes.

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## CONFLICT OF INTEREST

Authors declare 'no conflict of interest' with any researcher working on the aforementioned aspects in India or abroad.

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