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EXPLORING MORPHOLOGICAL VARIABILITY IN CHICKPEA CULTIVATION

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Abstract

This study aimed to evaluate the performance and morphological variability of ten chickpea (Cicer arietinum) lines, utilizing biological material from the Vegetable Research and Development Station Bacău. Data collection included key phenological and agronomic parameters: germination days and rate, days to first flowering, 50% and 100% flowering, and pod maturity stages (50% and 90%). Morphological traits assessed included flower colour, number of flowers per peduncle, plant growth habit, pigmentation, leaf type, leaflet count, and plant height. Additionally, yield-related traits such as pod insertion height, number of pods per plant, seeds per pod, total seeds per plant, seed mass per plant, seed shape, surface texture, and colour were evaluated. Results highlighted significant variability among the lines in flowering time and pod maturity, with L4 showing early, synchronized flowering and L6 exhibiting the longest flowering period. Pod maturity analysis showed that most lines reached 50% maturity between 115-119 days, indicating a consistent development rate. This comprehensive evaluation provides valuable insights into chickpea genetic diversity, supporting future breeding programs, with phenotyping playing a key role in understanding the genetic potential and adaptability of the accessions.

Key words: *agronomic parameters, morphological traits, genetic diversity, breeding programs.*

INTRODUCTION

Chickpea (*Cicer arietinum*) is an economically valuable, diploid legume crop that is self-pollinating. With a genome size of approximately 740 Mbp, it is recognized for its rich nutritional composition and is widely grown for its substantial dietary benefits (Kumar et al., 2011).

Leguminous crops offer substantial nutritional benefits to humans, serving as rich sources of protein, omega-3 fatty acids, and essential macro- and micronutrients. Moreover, legumes contribute to agricultural sustainability by enhancing soil nitrogen levels. Globally, chickpeas rank as the second most important legume staple food crop, following dry beans. However, despite their notable advantages, legumes lag significantly behind cereals in genetic advancement. This disparity is primarily attributed to limited research efforts, constraints imposed by a narrow genetic base, and various biotic and abiotic challenges exacerbated by changing climatic conditions (Singh et al., 2022). Globally, two primary types of chickpea cultivars Kabuli and Desi are cultivated. Kabuli chickpeas are mainly grown in temperate regions, particularly in areas such as the Mediterranean, encompassing Western Asia, Northern Africa and Southern Europe. In contrast, Desi chickpeas are primarily cultivated in semi-arid tropical regions, including the Indian subcontinent and Ethiopia (Muehlbauer and Singh, 1987). Desi chickpeas are typically characterized by small, angular seeds with a rough, pink or purple flowers and dark seed coat, which result from the presence of anthocyanin pigments. In comparison, Kabuli chickpeas have larger, smooth-surfaced, beige seeds that are owl-shaped and produce white flowers due to the absence of anthocyanin pigments (Pundir et al., 1985). Additionally, Desi-type chickpeas tend to mature earlier and exhibit higher yields than Kabuli types. Achieving high yields in various agroecological regions requires rapid seedling establishment and uniform plant stands, both of which are influenced by seed vigour. Variations in seed vigour among legume crops have been linked to differences in seed coat pigmentation (Dickson and Petzoldt, 1988; Kantar et al., 1996). Cultivated chickpeas, including Desi and Kabuli types, are derived from diverse genetic pools with distinct agronomic characteristics and are thought to trace their origins to the wild progenitor *Cicer reticulatum*. Recently, draft genome sequences for these varieties have been completed (Jain et al., 2013). A critical agronomic trait in chickpeas is their growth habit, which shows significant variation among Desi, Kabuli, and wild accessions (Upadhyaya et al., 2006). Typically, Desi and Kabuli chickpea cultivars display an erect to semi-erect growth pattern, while wild species accessions often exhibit a prostrate growth form (Wang and Li, 2008). The growth habit is a fundamental factor in determining plant architecture. It significantly influences key traits related to seed and pod yield and plays an essential role in the adaptation of chickpea plant types to diverse agroecological conditions (Benlloch et al., 2015; Upadhyaya et al., 2017). In chickpeas, the leaves, stems, and pods are covered with glandular trichomes that secrete acidic aqueous exudate, acting as a potential defence mechanism against *Helicoverpa armigera* infestation (Brar & Singh, 2017). Chickpeas exhibit superior performance in cooler climates due to their classification as C3 plants, which are generally better adapted to winter conditions (Pânzaru et al., 2022). Nevertheless, the harvest index (HI) for pulses, ranging between 15% and 20%, remains considerably lower than that of cereals, which typically fall within the 45-50% range a disparity that presents a significant challenge. This issue primarily arises from excessive vegetative growth, which may be mitigated through the early allocation of dry matter toward seed development (Saxena and Johansen, 1990). The determination of the significance and efficiency of yield components represents a primary objective in agricultural research. Additionally, the interplay between yield attributes and overall yield can vary across different trials, agronomic practices, and breeding initiatives. Identifying and optimizing the influential yield components, as well as understanding their interrelationships, can result in substantial yield improvements and enhanced outcomes (Kayan & Adak, 2012).

Research conducted by İslam and Begüm (1985), Khan et al. (1989), Gravaes & Helms (1992), and Toker & Cagirgan (2004) has demonstrated a positive association between grain yield and traits like plant height, branch number, and pod count per plant. Conversely, grain yield exhibits a significant negative correlation with traits such as days to maturity and flowering time (Ali & Ahsan, 2012; Mallu et al., 2015). Grain yield in chickpea is a quantitative trait influenced by a combination of genetic factors and environmental variations (Muehlbauer and Singh, 1987). Kayan and Adak (2012) further identified plant height, biological yield per plant, and the number of pods per plant as the most critical yield determinants in chickpea production.

Despite persistent efforts from national and international chickpea enhancement initiatives over the past several decades, notable improvements in chickpea yield and productivity have yet to be realized (Singh et al., 2022). In this context, the study aimed to evaluate the performance and morphological variability of ten chickpea lines. This information supports future breeding programs, highlighting the crucial role of phenotyping in understanding the genetic potential and adaptability of these accessions.

MATERIALS AND METHODS

The experiment was conducted at the Vegetable Research and Development Station in Bacău during the year 2024. The biological material consisted of ten chickpea lines (15 seeds per line) sourced from the same research station. The trial setup utilized seedlings cultivated in alveolar trays containing 70 alveoli. Sowing took place on April 11^{th}, employing a textured substrate with moderate fertilization enriched with micronutrients. The resulting seedlings were subsequently transplanted on June 5, into pots with a diameter of 30 cm and a height of 22 cm. The plants were cultivated outdoors and protected with a shading net to regulate environmental conditions. The descriptors for developping evaluation sheets and characterizing the breeding material for the chickpea species were selected and standardized from the following sources: Descriptors for Chickpea (*Cicer arietinum* L.) (IBPGR/ICRISAT/ICARDA,

1993) and Biology of *Cicer arietinum* L. (Chickpea) (Office of the Gene Technology Regulator, 2019), in accordance with UPOV guidelines (UPOV, 2020). The descriptors used for analysing chickpea germplasm was assessed based on the following criteria:

Germination and Growth Stages

The germination and growth stages of chickpea were evaluated based on several key indicators. The germination onset was recorded as the number of days from sowing until seedling emergence. Flowering onset was determined by the number of days from sowing until the appearance of the first open flower. The 50% flowering stage was defined as the number of days from sowing until half of the plants exhibited flowers, while the 100% flowering stage was marked by the number of days required for all plants to produce flowers (IBPGR/ICRISAT/ICARDA, 1993).

Reproductive Development

The reproductive development of chickpea was assessed using several key parameters. Flower colour was recorded for newly opened flowers and categorized as dark pink, pink, blue, or white (Figure 1).

Figure 1. Flower color for chickpea: A - white; B - pink (original)

Pod appearance was determined by noting the number of days from sowing until the formation of the first pods. The 50% pod maturity stage was defined as the number of days from sowing until half of the pods reached maturity, while the 90% pod maturity stage indicated the time taken for 90% of the pods to mature. Additionally, the number of pods per plants was counted, and the number of pods per peduncle was recorded based on observations of the majority of peduncles.

Morphological Characteristics

The morphological characteristics of chickpea were evaluated based on several criteria. Anthocyanin pigmentation was observed at the base of the branches and categorized into three levels: no anthocyanin, moderate anthocyanin, and high anthocyanin (Figure 2).

Figure 2. Anthocyanin pigmentation for chickpea: A - No anthocyanin pigmentation; B - Anthocyanin pigmentation (original)

Pubescence intensity on the shoots was visually assessed and scored as low, moderate, or high. Growth habit was determined by measuring the angle of the main branches during the pod-filling stage, and classified into five categories: erect (0-15° from vertical), semi-erect (16-25°), semi-spreading (26-60°), spreading (61-80°), and prostrate (with branches spreading along the ground) (IBPGR/ICRISAT/ICARDA 1993).

Leaf and Plant Structure

The leaf and plant structure of chickpea was analyzed using several key descriptors. Leaf type was observed before maturity and classified into three categories: normal (pinnate), simple (with an undivided blade), and multipinnate (with multiple rachis divisions). The number of leaflets per leaf was determined by calculating the average from nine leaves, collected from three randomly selected plants at the pod-filling stage (IBPGR/ICRISAT/ICARDA 1993). Plant height was measured from the ground to the tip of the tallest stem when 50% of the pods had matured. Additionally, the first pod insertion height was recorded as the distance from the ground to the lowest pod, also measured at the 50% pod maturity stage

Pod and Seed Traits

Seed texture, assessed in mature seeds, is classified as smooth, rough, or tuberculate. Seed color: evaluated in mature seeds stored for no more than five months (Figure 3). Seed shape, observed in mature seeds and categorized as: angular (Desi type), pea-shaped, irregular (Kabuli type) (IBPGR/ICRISAT/ICARDA 1993, UPOV 2020).

Figure 3. Seed characteristics for chickpea (original)

Number of pods per plant: the average number of pods per plant.
Number of seeds per plant: the total number of seeds harvested from three representative plants.
Number of seeds per pod: the average number of seeds per pod.
Seed mass per plant (g): the total weight of all dried seeds.
The data were statistically analyzed in Excel, using means and standard deviations for result interpretation.

RESULTS AND DISCUSSIONS

The chickpea lines show considerable variation in germination percentage. Lines L1, L4, L5, L6, L9, and L10 have a high germination percentage, ranging from 80% to 100%. Lines L3 and L7 show lower germination percentages, with 46.7% and 26.7%, respectively. Line L8 has the lowest germination percentage, at 6.7%. Most lines started germination in a relatively short period, between 5 to 6 days. Line L8 had the longest time to first germination, 9 days, suggesting slower germination compared to the other lines. Lines L1, L4, L5, L6, L9, and L10 are the most efficient in terms of germination, with high germination percentages and relatively quick germination times (6 days or less). Lines L3, L7 and L8 require further attention, as they performed poorly in terms of germination. This may indicate they are more sensitive to environmental conditions or seed quality (Figure 4).

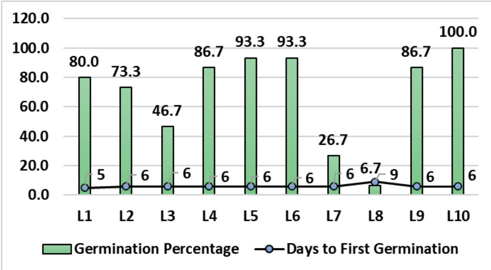

Figure 4. Comparison of Germination Days and Germination Rate in Chickpea Lines

The earliest flowering onset is observed in L4 (61 days after sowing), indicating a faster transition to reproductive phase (Figure 5). Most lines (L3, L5, L6, L7, L9) exhibit flowering onset around 71 days, suggesting a clustering of lines with a similar flowering pattern. Lines such as L1, L2, and L8 fall in the intermediate range between 66-68 days. L2, L4, and L8 exhibit the earliest completion of flowering (75 days), indicating a highly uniform flowering pattern across these lines.

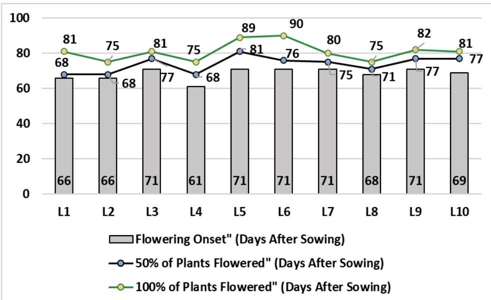

Figure 5. Chikpea flowering

L6 reaches 100% flowering at 90 days, demonstrating the highest variability among plants within this line, or a prolonged flowering duration. L4 shows early and synchronized flowering, making it suitable for environments requiring rapid maturation. L5 and L6 have the most extended flowering duration, indicating possible variability within the population, which could affect consistency in yield.

Most lines (L2, L4, L6, L7, L9, L10) mature around 115-119 days, showing a moderate and consistent pod development rate across these genotypes. Lines like L5, L6, L9, and L10 demonstrate prolonged pod maturity (90% at 144 days), which might be advantageous for yield potential but requires a longer growing season (Figure 6).

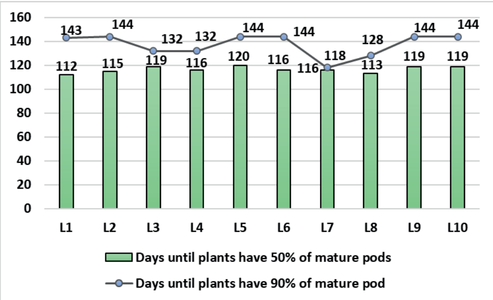

Figure 6. Pod Maturity Dynamics in Chickpea Lines

The variation in maturity duration among lines suggests genetic diversity, which can be utilized for developing varieties adapted to different climatic conditions or agricultural practices. This analysis highlights the importance of selecting chickpea lines based on their pod maturity profiles to optimize yield, resource use, and adaptability to specific environmental conditions (Figure 7).

Figure 7. Chickpea pods: A- green pods; B- mature pods (original)

All lines consistently produce one flower per peduncle. Lines with white flowers exhibit no anthocyanin pigmentation, while those with pink flowers show low anthocyanin levels (Table 1).

Table 1. Flower characteristics and pigmentation

Lines	Flower color	Number of flowers per peduncle	Plant: pigmentation
L1	white	1	No anthocyanin
L2	white	1	No anthocyanin
L3	white	1	No anthocyanin
L4	white	1	No anthocyanin
L5	pink	1	Low anthocyanin
L6	pink	1	Low anthocyanin
L7	white	1	No anthocyanin
L8	white	1	No anthocyanin
L9	pink	1	Low anthocyanin
L10	pink	1	Low anthocyanin

Most lines exhibit moderate pubescence, except for L8, which has low pubescence (Table 2).

Table 2. Morphological characteristics of chickpea lines

Lines	Plant pubescence	Plant: growth habi	Leaf: type
L1	Moderate pubescence	Semi- spreading	Normal (uni-imparipinnate)
L2	Moderate pubescence	Semi- spreading	Normal (uni-imparipinnate)
L3	Moderate pubescence	Semi- spreading	Normal (uni-imparipinnate)
L4	Moderate pubescence	Semi-spreading/Semi-erect	Normal (uni-imparipinnate)
L5	Moderate pubescence	Semi-spreading/Semi-erect	Normal (uni-imparipinnate)
L6	Moderate pubescence	Semi- spreading	Normal (uni-imparipinnate)
L7	Moderate pubescence	Semi- spreading	Normal (uni-imparipinnate)
L8	Low pubescence	Spreading/Semi-spreading	Normal (uni-imparipinnate)
L9	Moderate pubescence	Semi-spreading/Semi-erect	Normal (uni-imparipinnate)
L10	Moderate pubescence	Semi-spreading/Semi-erect	Normal (uni-imparipinnate)

The majority of lines exhibit a semi-spreading growth habit, with some lines (L4, L5, L9, L10) displaying semi-spreading to semi-erect tendencies. L8 stands out with a spreading to semi-spreading habit.

The consistent number of flowers per peduncle and leaf structure across all lines suggest stability in these traits, while variations in flower color, pigmentation, and growth habit highlight potential genetic diversity.

This variability, particularly in pubescence and growth habit, may influence adaptation to different environmental conditions and overall plant performance.
Plant height varies across lines, with L9 exhibiting the highest value (70.5 cm), while L7 show the lowest (41.5 cm) (Figure 8).

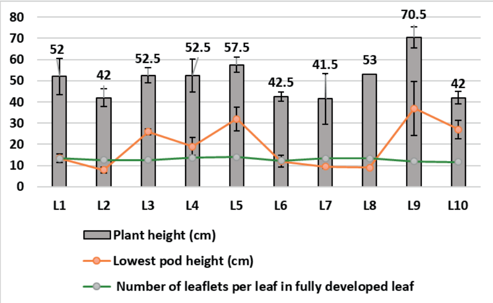

Figure 8. Comparative Analysis of Plant Height, Lowest Pod Height, and Leaflet Number in 10 Chickpea Lines

The number of leaflets per leaf remains relatively consistent across all lines, indicating stability in this trait. In contrast, lowest pod height fluctuates more significantly, suggesting potential differences in plant architecture or flowering pattern that may impact harvestability (Figure 9).

Figure 9. Chickpea lowest pod height (original)

L2 and L5 show the highest number of seeds per plant (94.7 and 95.0, respectively), while L9 has the lowest (39.0). The number of pods per plant varies across the lines, with L2 showing the highest value and L9 the lowest. The seed yield per plant remains relatively low, with L2 demonstrating the highest yield (27.5 g), suggesting potential correlations between pod number, seed number, and overall yield efficiency (Figure 10).

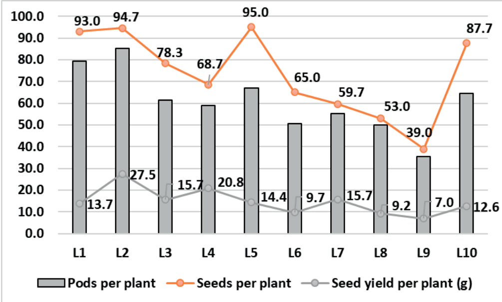

Figure 10. Pod Production, Seed Count, and Seed Yield per Plant Across 10 Chickpea Lines

The distinction between Kabuli and Desi types is evident in seed shape, surface texture, and color, with Kabuli lines characterized by smooth, beige seeds and Desi lines by tuberculate, darker-colored seeds (Table 3).

Table 3. Seeds characteristics of chickpea lines

Lines	Seed shape	Seed surface	Seed: colour	Seeds per pod
L1	Pea-shape - Irregular (Kabuli types)	Smooth	Beige	1/2
L2	Irregular (Kabuli types)	Tuberculate	Beige	1/2
L3	Pea-shape - Irregular (Kabuli types)	Smooth	Beige	1/2
L4	Pea-shape - Irregular (Kabuli types)	Smooth	Beige	1/2
L5	Angular (Desi types)	Tuberculate	Brown	1/2
L6	Angular (Desi types)	Tuberculate	Black	1/2
L7	Pea-shape - Irregular (Kabuli types)	Smooth	Beige	1/2
L8	Pea-shape - Irregular (Kabuli types)	Smooth	Beige	1/2
L9	Angular (Desi types)	Tuberculate	Brown	1/2
L10	Angular (Desi types)	Tuberculate	Black	1/2

This variability suggests different genetic backgrounds, with kabuli types typically preferred for culinary applications, while Desi types may offer greater resilience in diverse environments.
Despite differences in plant height, pod characteristics, and growth habits, the consistent number of flowers per peduncle and seeds per pod across all lines indicates genetic stability for these traits. However, variability in pod yield, plant architecture, and pubescence levels

suggests opportunities to select or breed for enhanced performance in specific environments or cultivation practices.

Desi lines (angular seeds, tuberculate surface, darker colours) and Kabuli lines (smooth, beige seeds) show distinct seed traits. However, seed yield per plant varies widely among the lines, with L2 having the highest yield and L9 the lowest. This indicates that seed surface and colour may not directly correlate with yield, highlighting the need to consider other agronomic factors when selecting high-yielding lines.

L5, L9, and L10, with their prolonged pod maturity (144 days) and angular "Desi" type seeds, could be suited for regions with extended growing seasons, contributing to enhanced yield stability under specific environmental conditions. Conversely, lines like L7 and L8, which mature faster, may be valuable for breeding early-maturing varieties to address water-limited or shorter-season environments.

CONCLUSIONS

Chickpea lines exhibit varied pod maturity, with 50% pod maturity ranging from 112 to 120 days and 90% pod maturity from 118 to 144 days, highlighting differences in growth cycle length.

Certain chickpea lines demonstrate valuable traits for future breeding and cultivation strategies. Lines such as L2 and L4 exhibit high seed yields combined with desirable plant architecture, making them potential candidates for developing high-yielding cultivars.

The highest seed yield per plant was recorded in L2, while the lowest yield was observed in L9, showing the influence of genetic traits and pod production.

The variability in seed shape, surface, and pigmentation across the lines indicates a broad genetic base that can be exploited for improving both yield and seed quality, aligning with market and environmental demands.

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