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Morphological and biochemical characterization of some chickpea (*Cicer arietinum* L.) genotypes in Bangladesh

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Abstract
A significant legume crop that is farmed all over the world is the chickpea (*Cicer arietinum* L.). In order to choose the promising lines, eleven chickpea advanced genotypes were assessed for yield, yield contributing features, and biochemical properties. Biochemical examination was carried out at the Bangladesh Institute of Nuclear Agriculture's Soil Science Division Laboratory, and the field experiment was carried out at the BINA sub-station, Ishwardi experimental field, during the Rabi season in 2022. Three replications of a randomized fully block design (RCBD) were used to conduct the field experiment. Ten randomly chosen plants from each plot were used to collect data on the following: number of primary branches, number of seed pods per plant, number of days to maturity, plant height, days of blooming, seed yield (tha^{-1}), and 100 seed weight (g). The seeds' protein percentage, nitrogen percentage, P, K, Na, Mg, Fe, Zn, Ca, and Ni contents were measured. The genotype BINA Sola-8 had the highest protein content (23.80%), whereas the genotypes CIEN-SSA 6-10 and CAT-29-38 had the lowest protein contents (11.89%). CIEN SSA-32-26 outperformed the control variety Binasola-8 and BARI sola-7, as well as other genotypes, in terms of seed yield (1.90 tha^{-1}) and pods plant^{-1} (98.58) at the BINA sub-station location in Ishwardi. In addition, out of all the genotypes, CIEN SSA-32-26 had the earliest maturity recorded (124 days). Additionally, the CIEN SSA-32-26 genotypes were enriched in Fe (200 ppm) and protein (17.62). The chickpea genotypes were quantified using both morphological and biochemical data, and the utilization of elite genotypes in breeding programs targeted at improving yield and nutritional quality may prove beneficial. In the upcoming season, more assessment will be carried out at various chickpea-growing region

Keywords: Chickpea, protein, biochemical, genotypes, atomic absorption spectrophotometer

Introduction
Chickpea (*Cicer arietinum*) is an annual legume of the family Fabaceae, subfamily Faboideae and it is cultivated in more than 40 countries worldwide and is the third most significant food legume (Singh, V. *et al*. 2021) [21]. With a diploid chromosome number (2n = 2x = 16) and papilionaceous corolla, it is a self-pollinating crop. According to Wood and Grusak (2007) [23], chickpeas are a rich source of calories, protein, minerals, vitamins, and fiber. They also include phytochemicals that may be good for your health. Chickpeas are grown on 12.7 million hectares of land in more than 54 countries worldwide, yielding 12 million tons annually (Devasirvatham, V., *et al*. 2018) [10]. About 12.55 thousand hectares of Bangladesh's 239.9 thousand hectares of pulse production are made up of chickpeas; with an average yield of about 766 kg ha^{-1}, chickpeas provide roughly 3.65% of the nation's total pulse production (Akter, M. 2019) [2]. Rainfed conditions have long been used in Bangladesh to cultivate chickpeas. Approximately 85% of the chickpea crop was planted in the districts of Jessore, Faridpur, Rajshahi, Kustia, Pabna, Chapai Nawabigonj, and Dinajpur (Abdur Rashid *et al*. 2014) [19]. The amount of land used for chickpea production has been rapidly decreasing due to the increased demand for staple crops including rice, maize, and wheat. In developing countries like Bangladesh, pulse can improve the overall nutritional value of a diet that is mostly composed of cereals. The average daily intake of pulses in Bangladesh is only 12 g head^{-1}, which is far less than the recommended 45 g head^{-1} (Bruinsma, J. 2017) [9].

Chickpeas are a significant source of protein for millions of people in developing countries. It has the highest protein content of any pulse at 25% and 60% carbs, according to Gaur *et al*. (2008) [12]. Chickpea seed proteins have lately attracted attention due to their anticancer, antidiabetic, and anti-HIV^{-1} reverse transcriptase qualities (Bhagyawant *et al*., 2018) [6]. This situation is becoming worse every day as a result of pulses' low yield and low nutritional content when compared to cereals. Chickpeas are less productive than cereals and are more susceptible to weather-related factors such drought, high soil moisture and humidity, heavy fertilizer and water use, and rainfall. These are the primary causes of its low yield. Increasing seed yield by creating diversity in the existing germplasm and then using the appropriate selection procedure is the primary prerequisite for enhancing chickpea cultivars. Given the present chickpea cultivars, it is imperative to assess the morphological and biochemical traits of these genotypes. The current study aims to generate a high-yielding, nutritious chickpea variety by investigating a number of biochemical and agronomic properties.

Materials and methods

Experimental site

The field experiment was carried out at the BINA sub-station in Ishwardi during the 2022 Rabi season.

Experimental treatments and design

Three replications and a completely randomized block design were used to set up the experiment. Two check variations with nine genotypes. CIEN SA-15, CIEN SSA-6-10, CIEN SSA-15-41, CIEN SSA-32-26, CAT-23-29, CIEN SA-33, CAT-11-28, CIEN-MED 32, and CAT-29-38 were the single factor genotypes used in the experiment, together with two check varieties, Binasola-8 and BARI sola-7. Line sowing was used to plant the seeds two to three centimeters deep. The unit plot measured 12 m² (4 m × 3 m). The line-to-line distance was kept at 40 cm, and the space between seeds was 10 cm in a row. During the last stages of land preparation, 45, 120, 70, and 90 kg ha^{-1} of urea, TSP, MoP, and Gypsum fertilizer were applied, respectively. To ensure the healthy growth and development of chickpea plants, standard intercultural procedures such as weeding, thinning, and pesticide treatment were carried out.

Data collection

Visual observation was used to record the number of days till 50% flowering (DF) and 95% maturity (DM) from the time of seeding until 50% flowering and 95% maturity, respectively. In accordance with established practice, morphological and yield-related characteristics were documented. A meter rod was used to measure the height of the plant from the base to the tip of the highest leaf. At maturity, the number of branches per plant (BPP) was manually counted. To record the grain yield, all genotypes were harvested at harvest maturity. Ten plants were chosen at random from each plot for this purpose, and the pods were threshed to determine the amount of seeds produced by each plant. To calculate seed production, which was adjusted to 12% moisture, all seeds (from ten plants) were weighed on an electric balance.

Determination of N, P, K, Na, Mg, Fe, Zn, Ca and Ni

Chickpea genotype seeds were ground into a fine powder for biochemical examination, which is then sieved and used for analysis.

Measurement of N

Johann Kjeldahl developed the Kjeldahl method in 1883 to determine the quantity of N. The three stages of the process are titration, distillation, and digesting. In this study, a machine called a "UKD 159 Automatic Distillation & Titration System" performed the distillation and titration processes, whereas the digestion process was carried out by hand. The UKD 159 Automatic Distillation & Titration System was used to measure the solution for every sample. The UKD 159 Automatic Distillation & Titration System reading revealed the total N% in each sample.

Measurement of P, K, Na, Mg, Fe, Zn, Ca and Ni

To measure each element's quantity, use a pipette. 10 ml of Barton's solution was added to 50 ml volumetric flasks containing 2 ml of each sample's diluted filtrate. Distilled water was then added to the solution to create volume. They then used an Atomic Absorption Spectrophotometer (AAS) to measure the amounts of P, K, Na, Mg, Fe, Zn, Ca, and Ni.

Estimation of Protein

Protein content was estimated by multiplying the percentage N by the conversion factor. A conversion factor (CF) of 6.25, or 0.16 g nitrogen per gram of protein, was employed to estimate the ratio of observed nitrogen concentration to protein concentration.

Analysis of data

The gathered data was statistically examined using the analysis of variance (ANOVA) approach. The statistical computer tool MSTAT-C was also used to calculate the simple correlation coefficient between significant characters and modify the mean differences using LSD.

Results and discussions

Plant height (cm)

In contrast to the genotypes, CIEN SA-15 had the shortest plants (69.31 cm), followed by BARI sola-7 (72.17 cm), while CAT-23-29 and CIEN SA-33 had the tallest plants (82.97 cm and 82.58 cm, respectively) (Table 1). Varietal variation is the main cause of variations in plant height between cultivars and varieties. Plant height and other agronomic characteristics may vary as a result of distinct genetic and morphologic factors, according to Singh and Verma (1999) [20].

Table 1: Different agronomic traits of selected chickpea genotypes

Genmo types	Plant height (cm)	Number of primary branches	Days of flowering (50%)	Number of pods plant^{-1}	Number of seed pod^{-1}
CIEN SA-15	69.31d	4.06b	72.36d	75.33de	1.60ab
CIEN SSA-6-10	75.27c	3.81bc	72.66cd	72.17ef	1.40bc
CIEN SSA-15-41	74.1c	3.22c	76.66ab	76.21cde	1.03de
CIEN SSA-32-26	73.63c	4.85a	72.33d	98.58a	1.83a
CAT-23-29	82.97a	3.73bc	77.66a	85.68b	1.43bc
CIEN SA-33	82.58a	3.84bc	74.33abcd	69.91ef	1.00e
CAT-29-38	75.23c	4.08b	76.00abc	66.41fg	1.30cd
CAT-11-28	80.58ab	3.75bc	73.66cd	62.66g	1.20cde
BARI sola-7	72.17cd	3.54bc	73.66bcd	82.52bc	1.63ab
CIEN-MED-32	79.06b	3.59bc	73.33bcd	74.48de	1.06de
BINA sola-8	73.25c	3.92bc	74.25abcd	81.18bcd	1.36bc
Level of Significance	**	*	**	**	**
CV (%)	2.7	10.85	2.85	5.36	11.93

Values having common letter(s) in a column do not differ significantly at 5% level as per LSD test

Number of primary branches plant^{-1}

The genotype CIEN SSA-15-41 (3.22) had the lowest primary branching frequency, whereas CAT-29-38, CAT-11-28, BARI sola-7, and CIEN-MED-32 had intermediates. The variety with the most primary branches plant-1 was CIEN SSA-32-26 (4.85) (Table 1). The maximum branching was discovered in CIEN SSA-32-26 because to its genetic composition and advantageous environmental conditions. The frequency of branching varied among genotypes that received the same treatment (Elobied, 2010) [11].

Days of flowering (50%)

The genotypes' flowering days varied significantly from one another. The genotype CAT-23-29 required the most days for flowering (77.66 days), while the genotype CIEN SSA-32-26 required the fewest days (72.33 days). Their genetic distinctiveness causes it to arise in the same agronomic setting. In chickpeas, germplasm from various parental sources with varying flowering times under identical agronomic conditions (Anon., 2006) [3]. Days to blooming were occasionally not important in certain variations of mungbean genotypes (Bhingarde and Dumbre, 1993) [7].

Number of pods plant^{-1}

In comparison to other chickpea genotypes, CIEN SSA-32-26 (98.58) had the most pods per plant, which was statistically significant. In contrast, CAT-11-28 (62.66) had the fewest pods per plant (Table 1). Due to the various genetic components of each genotype, pod number is a highly related gene-oriented feature that fluctuates. Variety had an effect on the quantity of pods that plants formed, according to Tahir *et al*. (2020) [22]. A germplasm's innate capacity to produce a certain number of pods per plant was noted by Özdemir and Karadavut (2003) [18]. Larger seeds produced a higher number of pods per plant, while smaller seeds produced fewer pods per plant, according to Bhingarde and Dumbre (1993) [7].

Number of seeds pod^{-1}

According to the findings, CIEN SA-33 had the fewest seeds (1.00) in a single pod, whereas CIEN SSA-32-26 had the most seeds (1.83), which was significant among the genotypes under study (Table 1). Because each variety has a distinct potential yield, the number of seeds in each pod varied. Larger seeds produced more seeds per pod, while smaller seeds produced fewer seeds per pod, according to Bhingarde and Dumbre (1993) [7]. According to Singh and Verma (1999) [20], genotypes under the same growing facility differed greatly in the quantity of grains pod^{-1}.

Days to maturity

The duration of the maturity stage was 124–134 days (Fig. 1). At 124 days, CIEN SSA-32-26 had the earliest maturity ever recorded. It differed significantly at all other genotypes. In comparison to other genotypes, CAT-11-28 exhibited the longest maturity length (134 days), which was statistically distinct. A species' blooming and pod formation phases were triggered by the same agronomic procedures for different genotypes because of the effects on the genes responsible for those traits. Bakr *et al*. reported similar results (2002). For field crops, days to maturity are influenced by environmental conditions and genetic diversity, according to (Anon., 2006) [3].

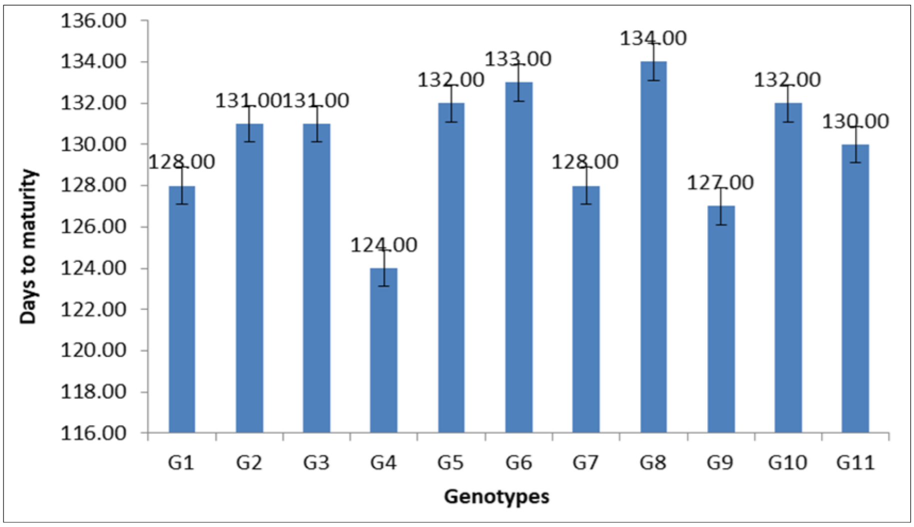

Fig 1: Days to maturity of different genotypes

100 seed weight (g)

CIEN SA-33 had the highest hundred seeds wt. (43.19 g), according to (Fig. 2), whereas BARI sola-7 had the lowest thousand seeds wt. (23.37 g). The parental genetic contribution governed this feature, which had a strong positive correlation with seed output. These results are consistent with a previous work by Li *et al*. (2015) [17], which indicated that the genotype mostly controlled the 100 seed weight under optimal conditions. Bakr *et al*. (2002) [4] found that the seed weights of BARI Chola-5 ranged from 110 to 120 g, BARI Chola-6 from 140 to 150 g, and BARI Chola-8 from 250 to 260 g.

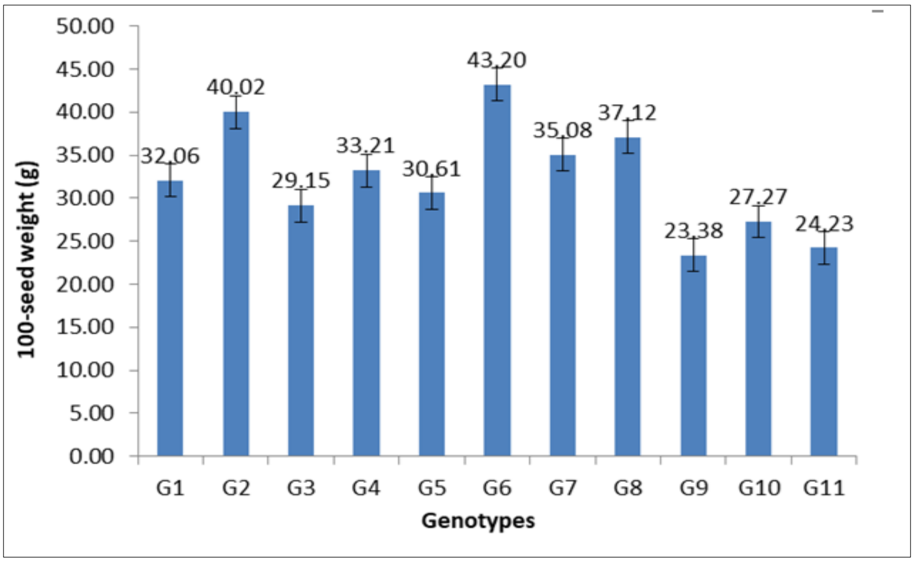

Fig 2: 100-seed weight (g) of different genotypes

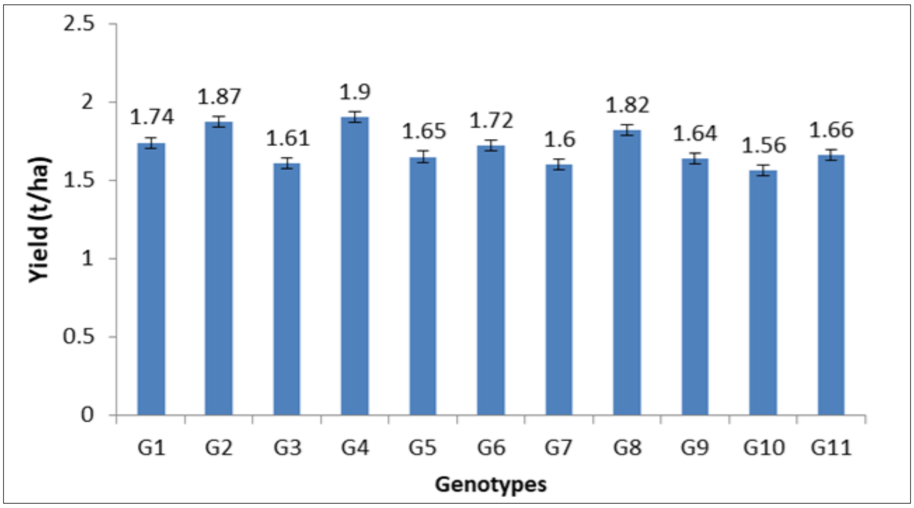

Fig 3: Yield of different chickpea genotype

Seed yield (tha^{-1})

Details about the genotypes of chickpeas' seed output are shown in Fig. 3. The difference in the seed yields of the several grown varieties was statistically significant; CIEN SSA-32-26 (1.90 tha^{-1}) had the largest seed yield, while CIEN-MED-32 (1.56 tha^{-1}) had the lowest. Similar findings were made by Akondo *et al*. in 2022 [1]. Although the number of branches has a substantial correlation with seed yield, the number of pods per plant and the number of seeds per pod have the greatest direct effects on seed yield (Lal *et al*., 2016) [16]. There were notable differences in the fresh weight of seed between cultivars (Jayaraj and Karivaratharaju, 1992) [13].

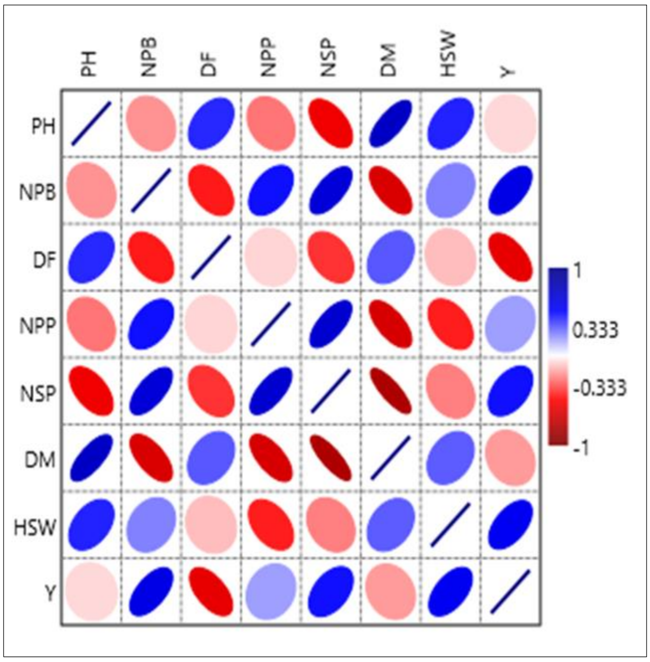

Fig 4: Correlation among the different morphological characters of chickpea genotypes

Correlations among agronomic traits

There were positive and statistically significant correlations between seed yield and the number of main branches per plant (NPB), number of pods per plant (NPP), and number of seeds per pod (NSP) (Fig. 4).

According to Khatun *et al*. (2009) [15], there is a positive link between seed yield and other factors that contribute to yield. Kante *et al*. (2022) [14]. Found a good correlation between the seed production of various sesame genotypes and a number of agronomic characteristics. The correlation study supports the findings that days to maturity, 1000 seed weight, and branches per plant are important yield-related characteristics. Again, a positive and significant association was observed between the number of pods per plant (NPP) and the number of seeds per pod (NSP). Additionally, plant height and days to flowering (DF) were positively correlated (Fig. 4). But the number of major branches, the number of seeds per pod, and the yield were significantly correlated negatively with the number of days to maturity. Seed yield was somewhat inversely correlated with plant height.

Bio-chemical attributes

There was a significant biochemical difference between the genotypes. The genotype BINA Sola-8 had the highest protein content (23.80%), whereas the genotypes CIEN-SSA 6-10 and CAT-29-38 had the lowest protein content (11.89%) (Table 2). BARI Sola-7 had a considerable amount of nitrogen (3.16%), while CIEN-SSA 6-10 and CAT-29-38 had the lowest amount (1.90%). In CIEN-SSA 6-10, measurable levels of potassium and phosphorus were detected at 1.12% and 0.55%, respectively. However, the genotype BARI Sola-7 had the lowest levels of potassium and phosphorus, at 0.84% and 0.35%, respectively. Concentrations of iron and zinc in plant parts are another crucial indicator of micronutrient richness. CAT-11-28 had the greatest zinc concentration (63.88 ppm), whereas CIEN-SA 33 had the lowest (25.86 ppm). The genotypes with the lowest levels of iron were CIEN-SSA 6-10, CAT-23-29, and CIEN-SSA 15-41 (50 ppm), whereas the genotypes with the highest levels were CAT-29-38 and CIEN-SA 15 (175 ppm) (Table 2). Magnesium, sodium, and calcium were also detected in good amounts in the genotypes CIEN-SA 33 (0.251%), CAT-23-29 (0.2%), and CIEN-SSA 6-10 (1.435%), respectively. Similarly, the genotypes CIEN-SA 15, CAT-29-38 (0.10%), BARI Sola-7 (0.01%), and CIEN-SSA 32-26 (1.01%) have decreased levels of the micronutrient's magnesium, salt, and calcium. All genotypes had measurable levels of the other micronutrient, nickel.

Table 2: Biochemical contents of selected chickpea genotypes

Sample Name	Protein %	% N	% P	% K	Zn (ppm)	Fe (ppm)	% Mg	% Na	% Ca	Ni (ppm)
CIEN-SSA 32-26	17.62c	2.82b	0.41de	1.00a	43.60b	200.00a	0.21b	0.02cd	1.01d	Trace
CIEN-SA 33	18.45bc	2.95b	0.47bcd	1.04ab	25.86g	50.00e	0.25a	0.14b	1.10cd	Trace
CAT-11-28	14.84d	2.37e	0.47bcd	1.00ab	63.88a	150.00c	0.20b	0.02cd	1.10cd	Trace
BARI Sola-7	19.72b	3.16a	0.35e	0.84b	37.52cd	75.00d	0.21b	0.01d	1.28abc	Trace
CIEN-MED 32	15.51d	2.48d	0.41de	0.98ab	28.9fg	50.00e	0.21b	0.03c	1.10cd	Trace
BINA sola-8	23.80a	2.85b	0.42cde	1.06ab	36.7de	160.00c	0.17c	0.03c	1.27abc	Trace
CIEN-SA 15	14.55d	2.33e	0.53ab	1.08a	31.43efg	175.00b	0.10e	0.02cd	1.35abc	Trace
CIEN-SSA 6-10	11.89e	1.90g	0.55a	1.12a	42.59bc	50.00e	0.12d	0.02cd	1.43a	Trace
CAT- 23-29	14.20d	2.27ef	0.55a	1.04ab	32.45def	50.00e	0.13d	0.20a	1.39ab	Trace
CIEN-SSA 15-41	14.20d	2.68c	0.41de	1.04ab	43.98b	50.00e	0.12d	0.02cd	1.18bcd	Trace
CAT- 29-38	11.89e	1.90g	0.49abc	1.08a	35.49de	175.00b	0.10e	0.02cd	1.30abc	Trace
Level of significance	**	**	**	*	**	**	**	**	*	-
CV (%)	6.48	6.23	9.81	13.19	8.64	7.43	5.04	13.54	12.00	-

Values having common letter(s) in a column do not differ significantly at 5% level as per LSD test

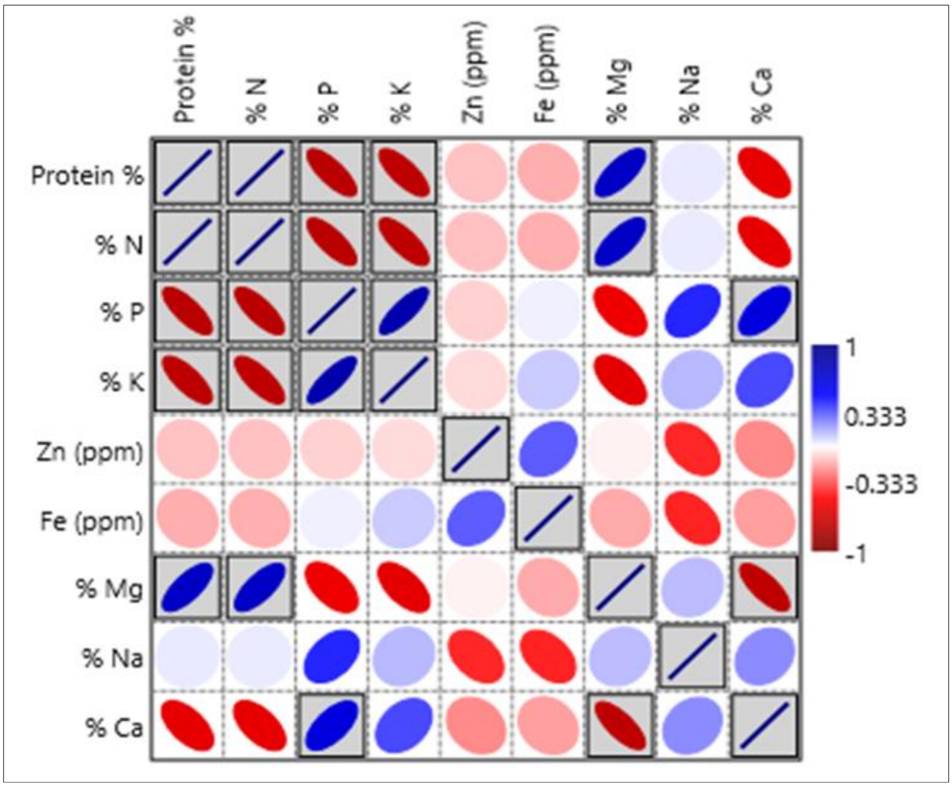

Fig 5: Correlation among biochemical components of selected chickpea genotypes

Correlation among the bio-chemical traits

The amount of protein and nitrogen are significantly positively correlated. Magnesium also has a positive association with protein concentration and nitrogen. Additionally, there is a strong positive association between phosphorus and calcium and potassium levels (Fig. 5). According to Bhagat *et al*. (2023) [5], there is a positive link between micronutrients and the amount of nitrogen and protein found in plant components. On the other hand, there is a notable inverse relationship between nitrogen and protein concentration and potassium and phosphorus. Additionally, there is a strong inverse relationship between magnesium and calcium.

Conclusion

The genotypes of chickpeas studied in this study varied significantly, which could help choose those with the best chance of producing higher yields with higher nutritional value. According to the current study's findings, CIEN SSA-32-26 produced the most seeds and had the shortest duration of nutrient enrichment. To improve the chickpea varieties in Bangladesh, these genotypes could be used as a baseline and as a selection indicator for breeding programs. This study, however, is preliminary and requires additional assessment in Bangladesh's various chickpea-growing regions.

Conflicts of Interest Statement

The authors certify that they have no conflicts of interest and that their work is original.

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