

AUGMENTATION OF PRODUCTION CAPACITY OF BENGAL GRAM BY THE POTENTIALITY OF DIFFERENT APPROACHES OF GIBBERELLINS USE WITH OPTIMUM CONCENTRATION OF PHOSPHORUS AND SULPHUR

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Abstract: India is largest producer of gram and so shares a total 67.2% of global production. Nutrients deficiency particularly phosphorus (P) and sulphur (S) responsible for maximum flower drop at terminal stages of bengal gram results in loose productivity despite the maximum capacity to slow down flower drop. Therefore, pre-sowing seed and foliose action of gibberellins (GA₃) and macronutrients on flowering stage is of larger valuation to reduce this problem. Thus, a pot experiment plotted to study the influence of pre-soaking and post spray application of P, S and GA₃ alone or in combination of all treatments on quality, yield and growth parameters under open field conditions of Amroha district of the Uttar Pradesh. The study tells that pre-sowing soaking (10 h) treatments followed by post-sowing foliar spray of nutrients at flowering phase (70-80 DAS) optimum for realization of optimum increment in yield, growth and quality characters. Also, growth, photosynthesis and quality concerned attributes, were, highly strengthened with the joint application of P, S and GA₃ (seeds soaked with 10 h in 10⁻⁶ M GA₃) before sowing and sprayed at reproductive phase with joined treatments of GA₃ P + S. These results applied by researchers and policymakers to larger extent to ensure quality and productivity for the wellness of the growing Indian as well as South Asian population and globe as well to meet the adequate and cost effective protein needs of the peoples of the South Asia and globally too.

Keywords: Chickpea, nutrient, photosynthesis, protein content, soaking, sowing, seed yield,

Abbreviations: DAS (days after sowing), GA₃ (Gibberellic acid), P (Phosphorous), S (Sulphu).

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Introduction

India is the largest producer, consumer and occupies an area of 65.8 million hectares and contributes 24% to world's food basket (Reddy *et al.* 2013). Among the crops of pulses, Chickpea, third most important pulse crop globally after French bean and field peas, (*Cicer arietinum* L.) is a very important crop of semi-arid tropics including India and fourth most important grain legume crop in the world with a total production of 11.00 million tones (Mt) from an area of about 13.00 million hectare (Anonymous, 2022; DES, 2023) and it is mostly grown in South Asia, which accounts for more than 75% of global production. India largest producer, contributing highest share in area (65.3%) and production (67.2%) of global (Anonymous, 2022; DES, 2023). Rainfed agriculture exhibits reduced biomass accumulation due to

limited soil water content, restricted nutrient accessibility, and consequent declines in productivity. About 9 Mt of this crop produced from 9.00 M ha areas during 2021-22 (Anonymous, 2022; DES, 2023) and crop production needs to double by 2050 to meet the growing population's increasing demand for food and energy (Ray *et al.*, 2013; Vollset *et al.*, 2020). The area had reduced in entire Indo-Gangetic plains as well. In U. P., it down to 0.6 million ha in 2021-22. Therefore, raising productivity may be the important aspect to deal with it. Maharashtra accounts for 22.32% of the national cultivated area and contributes 20.12% to India's overall production.

The agronomists and crop physiologists have to effort to solve all the above-mentioned matter concerned to lower productivity. The most significant and applicable option is only to enhance per hectare productivity at any cost/strategy applied.



Addressing the constraints of low productivity and regional demand necessitates a comprehensive and integrated strategy. However, with the release of new varieties, it is imperative to work out the precise package of farm practices for particular agroclimatic circumstances so as to use their full potential as species, and even variety of the same species, differ in their nutrient inputs as well (Egesel *et al.* 2009) and majority of Indian farmers hardly ever apply fertilizer or use manure when growing legumes. A considerable concentration of fertilizers is remain in soil as it unavailable to the crop roots system as it grows due to various reasonable agronomic factors, Processes such as decomposition, leaching, immobilization, and volatilization contribute to nutrient losses. For instance, nearly 55% of soil-applied nitrogen [4], approximately 73% of soil-applied phosphorus, and around 62% of the applied sulphur from compound fertilizers are lost due to one or more of these mechanisms. The crop uses only roughly 15-20% of the applied P. Since, reserve phosphate or rock phosphate has very little or no P to it in neutral and alkaline soil. To counter this situation, other methods such as top-dressing, adopted. Reports tells that S states and showed that soils of rainfed area are different in S and this nutrient has become deficit is due to cultivation of HYV (high yielding varieties) use high grade S, and P based fertilizers known to increase crop yield and uptake of macro-nutrients especially N. Also, foliar application proved very much effective, valuable and efficient (Mazid 2014). The area, production and average productivity of chickpea in U.P. are 0.58 m ha and 12 q/ha, respectively. For chickpea case, there is a serious limitation on crop productivity, produce quality, fertilizer use efficiency and economic returns is being caused by severe S deficit occurring every year. Among different barriers responsible for the low productivity of chickpea includes poor soil quality (fertilizers).

To attain such a target, the application of PGRs and fertilizers, Gibberellins, widely used globally play an important and strategic role. It is further assumed that foliar application of a limited amount of P and/or S, either with or without optimal soaking, together with the appropriate GA₃ spray treatment, can markedly enhance performance. In view of these considerations, a experiment performed under the natural conditions of Amroha.

Materials and Methods

Prior to sowing, uniformly sized earthen pots (25 cm in height × 25 cm in diameter) were prepared, each filled with a soil and FYM mixture in a 4:1 ratio at 5 kg per pot. The physico-chemical properties of the soil-FYM mixture were analyzed as follows: texture—sandy loam; pH—8.0; electrical conductivity—0.65 dS m⁻¹; available N-P-K (kg/ha)—210, 34.32, and 209.20 respectively; and calcium carbonate content—0.15%.

A controlled pot experiment was carried out during the rabi season of 2021–2022 on chickpea variety PUSA-334 within the net house facility of the Department of Botany (Agronomy), SVU, Amroha. The soils of Amroha district resemble those of the central–western plains of Uttar Pradesh in both composition and profile. Geographically, it lies at 28.23°N latitude, 72.01°E longitude, with an average elevation of 190 m, covering an area of 3800.4 km². The region experiences a semi-subtropical climate characterized by hot, arid summers and relatively colder winters. Mean temperatures during December and January are around 18°C and 13.4°C, respectively. The district records an average annual

precipitation of 837.6 mm, of which more than 75% is concentrated within four months (June–September, extending slightly into November), while the remaining rainfall is occasionally received during winter. The good and vibrant quality seeds of the varieties of the Bengal gram like PUSA-334 purchased from the Indian Institute of Pulse research (IIPR) Kalyanpur, Kanpur. After selecting seeds of uniform size, healthy, and later on their viability tested through a short experiment. Seeds inoculated with the recommended strain of *Rhizobium* (JKLM 19E) and then sown in already filled pots. A 100 millilitre (mL) stock solution of GA at a concentration of 10⁻³ M was prepared beforehand for subsequent application to experimental pots at defined time intervals. For its preparation, GA was initially dissolved in 10 mL of ethyl alcohol, and the final volume was adjusted to 100 mL using double-distilled water (DDW).

A standardized basal dose comprising 30 kg N + 25 kg P₂O₅ per hectare (equivalent to 14.9 mg N + 12.4 mg P per kg soil) was uniformly supplied to all pots. At sowing, half of the nitrogen dose along with the full phosphorus amount was incorporated, while the remaining half of nitrogen was administered at 40 days after sowing (DAS). Diammonium phosphate (DAP) served as the primary source of both N and P, with additional fertilizers used to a limited extent. The residual nitrogen requirement was balanced through field-applied organic fertilizers, specifically urea. Each pot contained four transplanted seedlings (replicates). A water-sprayed control treatment was also included. The experimental layout followed a simple randomized design.

Sampling Techniques

At different sampling intervals, one plant was randomly selected from each pot (replicate) to evaluate performance based on parameters such as shoot length per plant, leaf area index (LAI), photosynthetic rate (PN), chlorophyll content (Chl), and stomatal conductance (gs) at 100 and 110 days after sowing (DAS). At harvest, observations included seed number per pod, biomass yield (BY), and total seed protein content. Length of shoot on per plant basis determined by scale and LAI estimated through the help of the following formula:

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

The chlorophyll content estimated in leaves collected from each replicate by the method (Arnon, 1949). Photosynthetic rate (PN) was determined in fully expanded leaves of nearly identical age across all replicates using an Infrared Gas Analyzer (IRGA, LICOR-6400, Nebraska, USA). The PN values were expressed as μmol (CO₂) m⁻² s⁻¹. Stomatal conductance (gs) was recorded simultaneously with PN using the same instrument and expressed in mol m⁻² s⁻¹. Seed yield per plant along with yield-related traits was assessed from plants not sampled for biomass at harvest, coinciding with crop maturity, which differs regionally in India, e.g., Central versus Northern zones. Total pod number and seeds per pod were quantified from two representative plants, with seed weight recorded accordingly. Biomass yield (BY) was estimated by weighing the oven-dried mass of two whole plants using an electronic balance, and results were expressed on a per-plant basis. Protein concentration in dry seeds was determined following the method of Lowry *et al.* (1951).

Data Analysis

The data analyzed statistically by analysis of variance technique (Gomez and Gomez, 1984). Replicates were analyzed using the F-test, and the calculated 'F' value was found to be significant at the 5% probability level. The critical difference (CD) was subsequently computed.

Results and Discussion

The treatments exerted a significant influence on shoot length per plant as well as on the leaf area index (LAI) per plant. studied at 100 and 110 DAS explains that combined use of GA₃, P and S (S_{GA}+F_{GAPS}) increased growth, biochemical and quality characters. Also, it noticed as better among all the treatments for studied features. Moreover, the combined application of pre-sowing seed treatment with GA along with foliar spraying of GA, P, and S (S_{GA}+F_{GAPS}) recorded the maximum values across both sampling stages. Under this treatment, shoot length per plant increased by 81.89% and 74.84%, while leaf area index (LAI) rose by 212.34% and 184.23% at 100 and 110 DAS, respectively, when compared with the water-sprayed control (FW).

The treatments showed a significant impact on all evaluated biochemical parameters at 100 and 110 DAS, with the exception of stomatal conductance (gs) at both stages. Treatment S_{GA}+ F_{GAPS} gave 24.00 and 21.00 % for nodule-N content; 46.50 and 47.11% for Chl content and 63.14 and 63.21% for P_N, higher value at 100 and 110 DAS respectively than control (F_w). The effect of treatments reported significant on yield parameters at harvest. Treatment S_{GA}+F_{GAPS} gave 118.12% higher value for pod number per plant; 161.11% for pod weight; 198% for seed number per pod; 119.10% for 100-SW; 19.21% for average-seed weight per plant; 65.11% for BY; 87.18 % for HI and 84.10% for seed yield than control. Plants taken more N and P as result of the beneficial N fixation and P solubilization, allowed crop to grow much taller (Singh et al., 2016).

The SGA+FGAPS treatment recorded the highest values for both quality traits, producing a 20% increase in protein content compared to the FW control. The availability of P and S to pulses affects production of dry material and partitioning of photosynthetic materials (Mazid and Naqvi 2014). Maximum dry weight might be of phosphorous action, that is an energy-bonding substance and essential for energy conversion needed for almost all metabolic functions such as glucose metabolism, respiration, cell lengthening, cell division and stimulation of amino acids for making proteins; all these enhance the plant's dry weight and various other growth and development related factors (Kumar et al., 2024). Being nitrogen-fixing plants, gram crops require phosphorus not only for proper growth but also for effective nodulation. Highest number of nodules per plant observed as result of the crop receiving an adequate amount of P encouraged enhanced growth of root as well as nodulation, increasing the upper soil layer's absorption and accessibility of the N, P and S (Alukh and Pasricha, 2017). The influence of P on symbiotic N-fixation in gram has received considerable attention (Tsvetkova and Georgiev 2003). Nutrient demand is influenced by several factors as well as the balance among different elements, since the uptake of one nutrient may exert synergistic or antagonistic effects on the absorption of others. An improvement in phosphorus acquisition has been observed with the application of sulfur-based

fertilizers. Seed yield per unit area is a function critically to a greater extent of the combined effect of all the individual yield components studied influenced separately by the different agronomic practices and environmental reasons (Mohammad 2004). GA was observed to influence overall plant performance. GA mediating leaf expansion, Cori cycle, photosynthesis, respiration, N-fixation, T.C.A. cycle, E.M.P. pathway, Beta-oxidation, fat metabolism and development of the cell organelles and synthesis of hydrolytic enzymes flower and fruit set, photosynthesis, translocation of food material and synthesis of hydrolytic enzymes (Tiwari *et al.* 2011). Furthermore, GA enhances nutrient uptake and nutrient use efficiency (NUE), stimulates enzymatic activities, regulates cellular enzymes, promotes cell cycle progression, DNA replication, cell division, and enlargement. It also increases chlorophyll concentration, internode elongation, photosynthetic rate (PN), nucleic acid and protein synthesis, as well as the translocation of photosynthates. Foliar application of GA₃ could have led to the observed improvement in plant height and LAI per plant of the treated plants (Singh *et al.* 2004).

The promotive influence of foliar application of GA₃ at 60–70 DAS, compared with the water-sprayed control at 10⁻⁶ M, on plant height and leaf area index (LAI) per plant in chickpea supplied with the recommended basal dose of 40 kg N + 30 kg P₂O₅/ha, can be attributed to its comparatively diverse roles in plant growth and development. These results corroborate the results of previous workers including Yadav and Bharud (2006) and Mazid *et al.* (2014 a & b). The growth-promoting effect of pre-sowing seed treatment for 8 hours and foliar application of 10⁻⁶ M GA₃ at 70 and 80 DAS, compared with their respective controls, on plant height and LAI may be interpreted in terms of its functions in regulating cell division, cytokinesis, cell-plate formation, phragmoplast, and The initiation of cell differentiation, along with the external supply of GA₃ through pre-sowing seed treatment or foliar spraying, effectively compensates for the latent demand ('hidden hunger') of developing crops for GA₃. Similar results have been obtained by a few workers including Jafri (2009) and Thakare *et al.* (2011) on pre-sowing seed treatment and Kumar *et al.* (1996) and Singh *et al.* (2004) on foliage application of GA.

Moreover, the stimulatory influence of applying a small dose of P and/or S, either individually or in combination with seed soaking and/or foliar application of GA₃, compared with their respective controls, on growth attributes under the recommended basal supply of N and P, is a notable finding. The growth-promoting role of P and S can be attributed to their diverse physiological functions. In addition, S also plays an important role in various continuous metabolic processes as it is an integral part of several other metabolites, including adenosine-5-phosphosulphate, biotin, co-enzyme A, methionine, lysine, cysteine, cystine, enzymes, lipoic acid, methionine, 3-phosphoadenosine-5-phosphosulphate, proteins, fatty acids, thiamine and thiamine pyro-phosphate (Egesel *et al.* 2013). Pulses, in general, and particularly in chickpea, phosphorus is essential for growth and nitrogen fixation, as it supports stronger root development, which is crucial for crops cultivated under rainfed conditions. In recent years a good response of chickpea P fertilizer has been obtained (Singh *et al.* 2000). If the phosphate availability from the soil is limited, the growth and N fixation are affected (Prasad and Sonoria 1981). In addition, the role of phosphorus in

promoting root development, enhancing nodule formation, facilitating nitrogen fixation, and influencing nutrient uptake is well recognized to a considerable extent.

The key macronutrients, phosphorus (P) and sulfur (S), contribute either directly or indirectly to the growth of chickpea cultivars by supporting the synthesis of metabolic compounds and promoting nodule formation. Chickpea nodules are site of only *rhizobia* and bacteroids and also the site of N- reduction. A wide range of rhizobial and non-rhizobial genera are present within nodule cells and may serve as effective inoculants for improving crop productivity and yield. A wide range of rhizobial and non-rhizobial genera are present within nodule cells and may serve as effective inoculants for improving crop productivity and yield. Moreover, better growth with increasing S levels might be due to better utilization of resources under improved S supply, because it plays multiple role in plant metabolism as an essential constituent of S-containing amino acids like methionine, and Cysteine, and as such of proteins, vitamins, alkyl Co-A, cost of cultivation (Ruchi *et al.* 2012). These metabolites, in turn, stimulate the initiation and expansion of new cells in treated plants, resulting in greater plant height and an increased leaf area index (LAI) to a considerable extent. It is added that these findings on the improving effect of foliar treatment of P and S highly corroborate the previous results of Mazid (2014b; Vollset *et al.* 2023). Application of phosphorus led to a marked improvement in various growth traits, such as shoot length and leaf area index (LAI), which were further significantly influenced by the use of phosphorus- and sulfur-based fertilizers. This is due to production of growth regulators and availability of N which favor the growth characters. Moreover, nitrogen partitioning in winter-sown chickpea plays a crucial role in defining grain quality, as it directly influences plant protein content and the crop's capacity to achieve higher yields (Dauglas and Weaver, 1986; DES, 2023; Kumar *et al.*, 2024).

A comprehensive understanding of nitrogen nutrition in winter-grown chickpea is essential to optimize grain quality, yield, and overall productivity. The number of pods per plant was increased through phosphorus application (Singh *et al.*, 2016). Enhancements in shoot length, leaf number, and LAI in chickpea likely supported improved nodulation capacity, thereby facilitating greater nitrogen fixation. This is manifested in the observed improvement in plant height and LAI that is confirmed by correlation studies emphasizing a significant and positive contribution towards these growth parameters (Ray *et al.*, (2013); Gawhale *et al.* (2024). Moreover, GA₃ enhancing the rate of enzymes activities and absorption of nutrients responsible for improving the P_N, gs and Chl of treated plants and subsequently enhanced the content of Chl and leghaemoglobin. Also, P application affected total N accumulated which was due to an increase in growth of host plant than direct involvement of P in N fixation (Kobagapu *et al.*, 2019). Furthermore, elevated leghaemoglobin levels may contribute to increased chlorophyll content, thereby enhancing photosynthetic rate (PN). Foliar application of GA₃, compared with the control, resulted in a greater number of pods per plant and increased 100-seed weight. These improvements in yield components can be attributed to the multifaceted roles of GA₃, which led to higher values for growth traits as well as physiological and biochemical parameters in treated plants. In addition, GA₃ promotes cellular differentiation, resulting in a greater number of flowers that subsequently develop

into pods. As mentioned earlier, it plays role in cell division and cell enlargement resulting in proper development of under-developed pods especially at the terminal end of branches; P_N supplying sufficient C skeleton; and membrane permeability and transport of photosynthates favoring partitioning hence higher values for the yield parameters of treated plants (Taiz and Zeiger, 2010; Kumar and Mehera, 2022).

Additionally, chickpea plays an important role in enhancing soil fertility within cropping systems due to its ability to contribute nitrogen to the soil. A positive nitrogen balance is achieved only when the total N₂ fixed in plant residues surpasses the quantity of N removed. The nitrogen-fixing potential of chickpea can be improved through sufficient nutrient supply, particularly phosphorus and sulfur (Fayaz *et al.*, 2020). However, combined application of P and S have synergistic or antagonistic effects on crop yield, depending upon initial fertility status of soil, level of nutrients applied and test crop (Islam and Ali 2009; Kobagapu *et al.*, 2019). The enhancing influence of pre-sowing seed treatment with 10⁻⁶ M GA₃ for 8 hours, compared with the control, on pod number per plant and seeds per pod, as well as the positive effect of foliar application at 70 and 80 DAS with the same GA₃ concentration on these traits and 100-seed weight, is evident. This response can be attributed to the mitigation of the 'hidden hunger' for GA₃ supplied through seed treatment or foliar application. Similar results also obtained by Jafri (2009) and Dharwe *et al.* (2019).

Moreover, the observed improvements in pods per plant, seeds per pod, and 100-seed weight of chickpea supplied with the recommended basal levels of N and P, as a result of foliar application of small doses of P and/or S, either individually or in combination with GA₃ seed soaking and/or foliar spray, compared with the control, are evident. The enhancement of these traits through P and S application may be attributed to their contribution in stimulating nutrient dynamics within the soil-plant system and supporting physiological processes in the plant. The nitrogen required for developing pods can be fulfilled through uptake from the soil and atmosphere, as well as by internal remobilization within the plant. Also, P and S influence differentiation in plants much in detail in physiology of the legume crops (Marschner 2002; Meena *et al.* 2024). The improvement in growth, physiological, biochemical and metabolic parameters which resulted from the spray of these nutrients together with enhancement in differentiation may lead to the improvement in yield characters, hence maximum values for pods/ plant, seeds/ pod and 100-seed weight, BY and HI (Dharwe *et al.* (2019). P and S both jointly or in particular GA₃ might have played important role in flowering, fertilization, hormonal metabolism and translocation of sugars and other elements from source to sink (El-Eyuoon and Amin, 2018). Therefore, plant height, number of pods per plant, seeds per pod, 100-seed weight, and harvest index (HI) emerged as the principal yield-determining traits in chickpea. GA₃ has definite role to play in the number of flowers produced and maintenance. The increased seed yield may be also due to the application of P, S together with GA₃ have helped the flowering process (Dharwe *et al.*, 2019; Singh *et al.* (2022). The retention and transformation of flowers into pods, along with a considerable increase in pod set, were observed. The HI was reported more in foliar application of P and S followed by soaking P, S with GA₃ and lowest in water sprayed control. This increase in HI is due to involvement of P, S and GA₃ in

translocation of sugars and other elements from source i.e., leaves to developing sink (pods and fruits). These results are in similar with the results of Narasimha Rao (2005) and Gawhale et al. (2024) on foliage application of P and S to greater extent.

The improvement in yield-contributing traits of treated plants, particularly pods per plant, 100-seed weight, and test weight, played a major role in enhancing overall seed yield. This increased of the seed yield is due to involvement of nutrient element, i.e., P and S and the hormone, GA₃ in the lipid and chlorophyll synthesis, photosynthetic activity, N-reduction, flower and fruit production, pod set, fruit set, and translocation of sugars, lipids from source to sink. Increase in seed yield due to P use is similar to those found by Aslam *et al.* (2005; Meena *et al.* 2024). Furthermore, at harvest, a higher seed yield (final out-put) reported and it was discovered that the application of P accelerated the production of photosynthesis while their movement from source to sink, increasing yield and contributing to characteristic traits (Kumar *et al.*, 2004 and Gawhale *et al.* (2024). Several other workers reported previously that application of P resulted a significant increase in yield contributing characters like number of pods per plant, number of seeds per pod and 100-seed weight (test weight) with increasing dose of P. All this happened due to P application accelerated the production of photosynthesis and translocation of photosynthates from source to sink that ultimately gave the higher values of yield contributing characters (Fayaz *et al.*, 2020; Kobagapu *et al.*, 2019; Kumar *et al.*, 2024).

Enough, P nutrition increases many parameters of plant biochemistry like photosynthesis, flowering, fruiting and maturation (Brady and Weil 2005). Enhancement in yield due to S application is due to the fact that S composition is associated to photosynthesis, an life supporting biochemical and physiological process for earth's fauna and flora. Gawhale *et al.* (2024) revealed that application of S through Bentonite sulphur resulted in the highest seed yield and straw yield followed by S through Gypsum + RDF. Likewise, the maximum number of pods per plant, test weight, protein concentration, and total chlorophyll were observed with the application of bentonite sulphur. In addition, treatments with bentonite sulphur and gypsum enhanced the content and uptake of N, P, K, and S, while sulphur application at sowing significantly improved yield, nutrient assimilation, protein levels, and chlorophyll content of chickpea grown in sulphur-deficient soils of the semi-arid regions of India. Similar results of enhanced seed yield due to application of S reported by Raina and Tanawade (2005) and Alukh and Pasricha (2017). The application of P fertilizer singly increase grain yield and hence productivity if water in not limiting (Madzivhandila *et al.* 2012). This assertion is further supported by correlation analyses, which revealed that various yield traits were positively and significantly associated with seed yield. The enhancement in seed protein and carbohydrate content resulting from foliar application and pre-sowing seed treatment with GA₃ is therefore not unexpected. An augmenting response in protein synthesis may result from the application of GA and P and S (Taiz and Zeiger 2010; Gawhale *et al.* 2024)), hence higher values for seed protein. These results broadly corroborate with the findings of Khafagy (1995) on GA₃ application and of Mansur *et al.* (2009) on P and S basal application on crops.

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Table.1.Effect of gibberellins, P and S on yield and component traits of chickpea at two sampling stages(100 and 110 days after sowing,

Treatment	Shoot length (cm)		Leaf area index		Nodule-Nitrogen		Net photosynthetic rate(P _N)		Stomatal conductance (gs)		Chlorophyll content (Chl)	
	90 DAS	100 DAS	90 DAS	100 DAS	90 DAS	100 DAS	90 DAS	100 DAS	90 DAS	100 DAS	90 DAS	100 DAS
F _W	36.10	38.00	15.20	17.40	2.99	2.60	7.16	6.64	0.190	0.170	1.690	1.720
F _P	38.70	40.00	16.90	17.90	2.30	2.70	8.10	7.54	0.192	0.170	1.810	1.840
F _S	39.20	40.00	23.20	24.10	2.84	2.80	8.27	7.84	0.197	0.172	1.940	1.970
F _{PS}	42.60	43.70	26.80	27.00	3.10	2.90	9.11	8.84	0.197	0.177	1.970	2.000
S _{GA}	40.30	42.10	28.70	31.20	2.40	3.00	7.61	8.20	0.200	0.192	2.140	2.210
S _{GA} +F _P	41.60	47.00	31.40	33.40	2.50	2.90	8.64	8.29	0.211	0.193	2.170	2.200
S _{GA} +F _S	45.80	47.20	30.90	35.20	2.60	2.50	8.94	8.40	0.213	0.190	2.190	2.200
S _{GA} +F _{PS}	47.20	48.80	37.10	39.40	2.70	3.20	9.27	8.24	0.213	0.200	2.240	2.290
F _{GA}	46.40	48.40	29.00	29.20	2.50	2.90	9.00	8.97	0.218	0.201	2.370	2.390
F _{GAP}	49.80	51.20	32.30	34.00	2.40	2.60	10.44	9.92	0.223	0.207	2.390	2.400
F _{GAS}	52.10	55.80	31.70	35.70	2.10	2.50	10.45	9.97	0.224	0.210	2.350	2.380
F _{GAPS}	54.80	56.10	36.50	40.00	3.20	3.10	10.40	10.13	0.218	0.210	2.400	2.410
S _{GA} +F _{GA}	54.20	61.20	41.20	41.40	3.20	3.00	10.40	10.10	0.211	0.211	2.420	2.500
S _{GA} +F _{GAP}	59.70	61.20	43.20	44.80	3.40	3.40	11.44	10.87	0.226	0.211	2.440	2.530
S _{GA} +F _{GAS}	65.20	67.00	42.00	45.70	3.50	3.50	11.54	10.98	0.217	0.209	2.430	2.490
S _{GA} +F _{GAPS}	67.40	68.00	48.40	49.80	3.60	3.60	11.76	10.70	0.227	0.225	2.470	2.560
C.D. at 5%	3.47	3.58	2.28	2.41	1.64	2.39	0.68	0.64	NS	NS	0.156	0.560

DAS) (*Cicer arietinum* L.)**Table.2. Effect of gibberellins , P and S on yield and component traits of chickpea at harvest (*Cicer arietinum* L.)**

Treatments	Pod number per plant	Pod weight per plant	Seed number per pod	100 seed weight per plant	Average seed weight (mg)	Seed yield per plant (g)	Test weight (g)	Biological yield per plant	HI (%)
F _w	15.20	21.20	1.00	17.10	113	2.670	11.20	5.760	30.20
F _P	17.40	23.90	1.25	18.30	102	3.120	12.00	6.230	41.40
F _S	18.25	24.50	1.50	19.00	105	3.000	12.60	7.300	39.50
F _{PS}	20.80	25.80	1.75	23.40	125	3.520	122.70	7.840	43.80
S _{GA}	24.10	24.50	1.75	24.70	112	3.930	11.10	7.630	49.10
S _{GA} + F _P	25.50	25.40	2.00	26.20	117	3.940	10.20	7.910	50.00
S _{GA} + F _S	28.30	25.70	2.00	29.30	123	3.830	13.00	7.830	52.40
S _{GA} + F _{PS}	27.20	26.30	2.00	33.40	126	4.000	13.90	8.110	56.30
F _{GA}	27.30	24.40	1.50	27.20	132	4.280	12.50	7.300	53.40
F _{GAP}	29.80	25.30	1.75	29.45	137	4.310	12.80	7.240	55.20
F _{GAS}	30.00	26.20	2.00	31.20	147	4.420	13.20	8.320	57.80
F _{GAPS}	30.90	27.40	2.25	33.00	150	4.470	13.40	8.730	54.30
S _{GA} +F _{GA}	28.10	30.30	2.00	29.40	153	4.720	12.00	8.310	55.30
S _{GA} +F _{GAP}	29.40	32.40	2.50	31.60	165	4.830	13.50	8.830	56.70
S _{GA} + F _{GAS}	33.20	34.90	2.75	35.10	166	4.900	14.00	9.700	58.90
S _{GA} +F _{GAPS}	33.10	35.00	3.00	37.80	176	4.970	14.50	9.800	59.10
C.D. at 5%	1.85	0.45	0.14	1.96	1.65	0.286	NS	0.520	NS

N.B. : A uniform basal dose of 40 kg N + 30 kg P₂O₅/ha was given to all pots.

Table 3. Correlation coefficient (r) values for different pairs of significant characteristics

Characteristics	Pod number per plant	Seed number per pod	100-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Seed protein content
Pod number per plant	—	0.865	0.986	0.746	0.685	0.718	0.539
Seed number per pod	—	—	0.754	0.933	0.742	0.749	0.885
100-seed weight	—	—	—	0.763	0.844	0.619	0.825
Seed yield per plant	—	—	—	—	0.875	0.790	0.766
Biological yield per plant	—	—	—	—	—	0.798	0.773
Harvest index	—	—	—	—	—	—	0.846

r value

Significant at 5% 0.497

Significant at 1% 0.623

Table 4. Correlation coefficient (r) values for different pairs of significant characteristics

Characteristics	Sampling stages (DAS)	Pod number per plant	Seed number per pod	100-seed weight	Seed yield per plant	Biological yield per plant	Harvest index	Seed protein content
Shoot length per plant	90	0.894	0.789	0.799	0.785	0.908	0.678	0.859
	100	0.675	0.911	0.765	0.675	0.593	0.869	0.668
Leaf area index	90	0.672	0.723	0.858	0.885	0.757	0.689	0.796
	100	0.798	0.898	0.795	0.584	0.758	0.564	0.859
Nodule content N	90	0.674	0.684	0.858	0.984	0.684	0.673	0.549
	100	0.894	0.548	0.859	0.855	0.959	0.758	0.994
PN per plant	90	0.675	0.859	0.850	0.724	0.855	0.969	0.699
	100	0.665	0.779	0.795	0.594	0.794	0.786	0.696
gs per plant	90	0.648	0.670	0.754	0.539	0.984	0.769	0.686
	100	0.774	0.758	0.995	0.874	0.858	0.789	0.694
Total leaf Chl per plant	90	0.858	0.559	0.658	0.896	0.869	0.564	0.648
	100	0.841	0.559	0.854	0.850	0.881	0.769	0.964

r value

Significant at 5% 0.487

Significant at 1% 0.612

Table 5. Physico-chemical characteristics of the mixture of soil and farmyard manure used for experiment

Experiment	
Soil characteristics	
(2021-2022)	
Texture	Sandy loam
pH (1:2)	7.87
E.C. (dSm ⁻¹)	0.67
Available N (kg N /ha)	188.00
Available P (kg P ₂ O ₅ /ha)	28.40
Available K (kg K ₂ O/ha)	224.00
Calcium carbonate (%)	0.06

Figure legends

Figure. 1. Effect of spray of P and / or S in the presence or absence of soaking and / or spray treatment of GA on seed yield per plant of variety PUSA-334 of chickpea

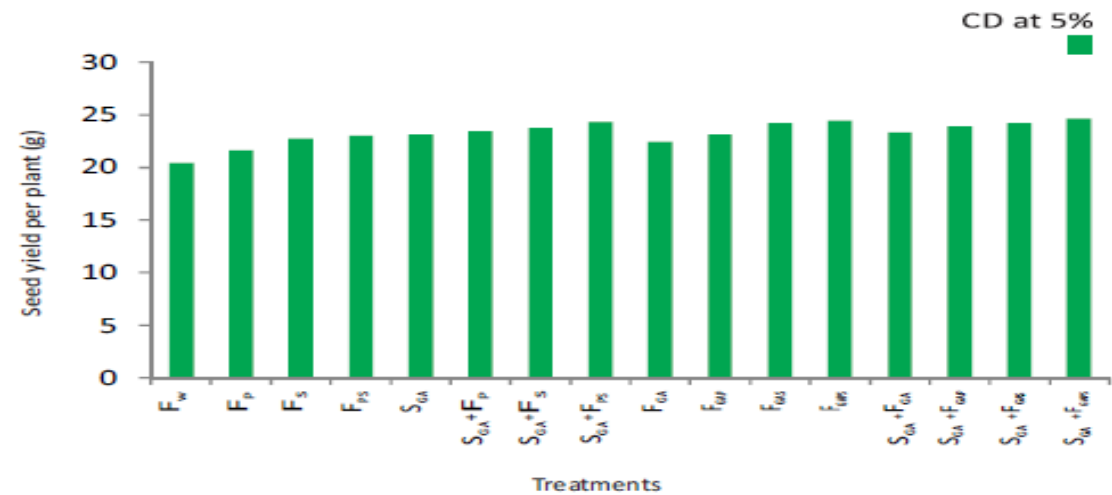


Figure. 2. Effect of spray of P and / or S in the presence or absence of soaking and / or spray treatment of GA on total seed protein content of variety PUSA-334 of chickpea

