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Growth and Yield Performance of Chickpea (*Cicer arietinum*) as Influenced by Irrigation Levels and Genotypes: A Review

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ABSTRACT

Chickpea is mostly cultivated under dryland condition and water availability is the major environmental factor affecting crop yield in dryland conditions. In dryland areas, the crop suffers from moisture stress due to the insecurity of rainfall. The combination of stored soil moisture and high temperatures results in the creation of various degrees of moisture stress during the duration of crop growth, therefore restricting the expression of growth and development characteristics, resulting in a significant loss of crop output. The provision of irrigation proves pivotal for the successful cultivation of chickpea crops during key growth stages, including pre-flowering, pod development and seed filling. Consequently, the implementation of supplemental irrigation serves as a strategic measure to offset potential production losses attributed to terminal drought. This agricultural practice is notably employed in diverse regions worldwide, with a pronounced impact observed in areas such as West Asia and Northern India, where it plays a crucial role in augmenting chickpea productivity. Susceptibility to drought stress has restrained chickpea productivity at a global level, thus, the proper selection of early maturing and drought tolerant cultivars along with supplemental irrigation may be helpful to sustain chickpea production.

Key words: Chickpea, Genotypes, Growth, Irrigation levels, Yield.

Chickpea (*Cicer arietinum* L.) is the leading pulse crop in India in terms of area, production and productivity and the third most important pulse crop globally (Dhaka *et al*., 2024; Vishnu *et al.,* 2020; Sihag *et al.,* 2019; Halagalimath and Rajkumara, 2018). As a legume crop, chickpea helps to maintain soil fertility and texture while fixing nitrogen in the soil, yielding a good yield while demanding less irrigation than many field crops (Kamal *et al.,* 2024). India is the world's largest producer and consumer of chickpeas, accounting for 69.7 per cent of global output and chickpea contributes for more than a third of country's total pulses area and almost 45% of pulse output. In India, chickpea was sown on an area of about 10.7 million hectares with a production of 13.5 million tonnes with an average productivity of 1261 kg ha^{-1} (Anonymous, 2022).

Currently about one-third of total world's population is living in water-deficit conditions and it is forecasted that drought stress is expected to increase because of elevated CO2 in atmosphere (Yücel, 2018; Karim *et al.,* 2021). Scientific research has demonstrated that water deficiency adversely affected the crop growth and productivity posing a serious threat for agriculture. Crop plants are suppressed by different biotic and abiotic stresses which acutely obstruct their growth, development and reproduction (Kamal *et al.,* 2023). The drought is the main abiotic constraint which account for 50% yield loss in chickpea (Harish *et al.,* 2020). Globally, approximately 73% of the chickpea cultivation area faces a reduction in soil moisture, subjecting the rain-fed crop to terminal drought and heat stresses throughout its vegetative and reproductive growth phases. Drought has a number of negative effects, including a loss in growth and a decrease in the chlorophyll content as a result of membrane injury (Kamboj, 2022). Excessive water stress during the critical stages may adversely affect the seed quality (Chauhan *et al.,* 2016). The responses of plants to drought stress exhibit variability based on the severity and duration of the stress, as well as the species of the plant and its growth stage (Dhaka *et al.,* 2023; Basu *et al.,* 2007). Plants employ strategies for drought adaptation and avoidance, such as the development of deep roots and increased root biomass (Chandler and Bartels, 2008). The soil's capacity to absorb water through the root system plays a pivotal role in regulating transpiration rates and facilitating drought adaptation. Under dryland conditions, there is considerable variation in the root depth among different genotypes (Kamboj *et al.,* 2021). Chickpea crop is generally relegated

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to marginal lands and many times no supplementary irrigation is provided. However, there are reports indicating improvement in several growth indices including yield of chickpea when supplementary irrigation is given (Kumar *et al.,* 2021; Moemeni *et al.,* 2013). Ulemale *et al.* (2013) found substantial differences between dry and irrigated conditions in respect of phenology, vegetative growth and development, physiological parameters and drought characteristics across the different chickpea genotypes. Drought resistance is linked to high relative water content and leaf water potential and these parameters have been recommended as more valuable indicators of plant water status under moisture stress than other water potential metrics. The importance of agro-physiological features linked with moisture stress in selecting acceptable selection criteria for moisture stress resistance cannot be overstated. Selecting cultivars with early maturation and drought tolerance, along with supplemental irrigation during the reproductive stage, emerges as a pivotal strategy for sustaining chickpea production (Sachdeva *et al.,* 2022). A brief summary of work done on the topic at various sites in India and overseas has been discussed in this review under the following headings.

Effect of irrigation levels and genotypes on the phenology of chickpea

Under moisture stress at vegetative stage, the chickpea variety Mastewal exhibited the longest flowering duration of 56 days, while the shortest duration of 32 days was observed in the Habru variety under optimal watering conditions (Mekonnen, 2020). The chickpea crop grown under rainfed environment attained early 50% flowering and physiological maturity (both 9 days earlier) in comparison to irrigated environment (Reeta, 2019). Tiwari *et al.* (2018) reported that moisture stress condition S6L (water withheld from 6 leaf stage) had the lowest days to flower initiation (39.5), days to 50% blossoming (45.7), days to pod onset (56.2), days to physiological maturity (112.5) and days to reproductive phase duration (73.0) as compared to SFL (water withheld from flowering) and S0 (non-stress) conditions. Also, days to flower initiation, days to 50% blooming, days to pod initiation and physiological maturity were all much lower in the KAK-2 chickpea variety, indicating that it is more resistant to moisture stress. Under drought conditions, Brahmane *et al.* (2017) found that the chickpea genotypes Vijay and Digvijay exhibited early characteristics, while PG-5 and Chaffa displayed a later onset for days to the commencement of flowering, 50% flowering and maturity. Swarup and Holkar (2014) concluded that the chickpea genotype IG 370 demonstrated early flowering and maturity compared to all the tested genotypes (IG 226, KAK, IG 592, Vishal, JG 412 and Ujjain 21) under both drought stress and non-stress conditions.

Chickpea plants cultivated in rainfed conditions exhibited an earlier flowering and maturation compared to those grown under irrigated conditions. In ICCV-4958, 50% flowering initiated in 78 days, compared to 92 days in H-208 under rainfed conditions (Kumar *et al.,* 2012). Khamssi *et al.* (2011) found that the chickpea cultivar Arman exhibited the highest grain filling rate, with significant differences from Hashem and Pirooz. Kumar *et al.* (2010) reported that the chickpea genotypes exhibited significant differences in days to 50% flowering. H 04-33 took 81 days for 50% flowering, while HC-5 and H 02-36 took 94 days for the same under comparable conditions. Sharma *et al.* (2007a) found that under mild and severe moisture stress, the maturity time of chickpea crop was shortened by 15 and 19 days, respectively over the irrigated control. Sharma *et al.* (2007b) observed that increased moisture stress initiated early flowering and pod formation in chickpea crop. The imposition of moisture stress in the rainout shelter treatment led to a reduction in the maturity duration by 15 days compared to the irrigated control. This reduction also translated to a diminished reproductive phase relative to the irrigated control. The chickpea genotypes ICC 4958 had the shortest maturity duration closely followed by K 850 and early attainment of 50% flowering followed by genotypes Annigeri and Tyson.

Effect of irrigation levels and genotypes on the growth of chickpea

A) Shoot growth

Mekonnen (2020) found that the growth parameters like plant height, number of primary and secondary branches, dry biomass and root dry weight were significantly higher for Mastewal variety as compared to Habru variety of chickpea. Sarkar and Sarkar (2019) reported that higher plant height of chickpea (61.44 cm) and dry matter accumulation (232 gm^{-2}) was recorded when irrigation provided at IW/CPE of 0.6 treatment compared to no irrigation (56.62 cm and 202.90 gm^{-2}, respectively) in legume-chickpea cropping sequence on sandy loam soil. Reeta (2019) found that the growth parameters of chickpea *viz*. plant height, dry matter accumulation, number of branches, number of nodules, dry weight of nodules and leaf area per plant were significantly higher in irrigated environment (where two irrigations were applied at pre-flowering stage and pod development stage) as compared to the rainfed environment. Under drought conditions, Brahmane *et al.* (2017) found that the chickpea genotypes Vishal, Vijay and Digvijay had larger dry matter buildup in the plant's component parts. According to Dharanguttikar *et al.* (2015), drought tolerance was observed in the chickpea cultivars NBeG 47-1, PBC-161 and BBG-2 for germination, GJG-1010 and PBC-161 for seedling growth and NBeG 47-1 and PBC-161 for enhanced dry matter accumulation. Dhima *et al.* (2015) reported that chickpea cultivation under irrigation, specifically with a water application of 30 + 30 mm, resulted in a substantial increase in total dry biomass and seed production compared to chickpea cultivation in non-irrigated conditions. Notably, irrigation administered during the

blossom growth stage contributed to an 18 per cent enhancement in the total dry weight of chickpea compared to non-irrigated chickpea. The total dry biomass of chickpea variety Amorgos was 10% and 13% higher than that of Serifos and Andros in irrigated conditions (30 + 30 mm of water) compared to non-irrigated conditions, with its corresponding seed yield increase being 5% and 16%. Randhawa *et al.* (2014) observed that limited irrigation lowered total stem biomass, resulting in reduced leaf area and leaf area index. The most pronounced decrease in height and branches was noted when irrigation was limited following pre-sowing irrigation. Among the various tested chickpea genotypes, GL 28151, RSG 963, PDG 3 maintained higher growth showing their tolerance to water stress, while GL 22044, RSG 1861 and RVSSG 4 were adversely affected in growth traits. Pawar *et al.* (2013) reported that irrigation in chickpea at 1.2 IW/CPE ratio showed significantly higher growth attributes *viz.*, numbers of branches (10.23), plant height (49.07 cm) and dry matter (31.7 g) as compared to 0.6, 0.8, 1.0 IW/CPE ratio and irrigation at critical growth stages. Zaman-Allah *et al.* (2011) found that the tolerant chickpea genotypes showed less canopy conductance at the vegetative stage, poorer early vigour, more restricted early leaf growth and a greater soil moisture threshold for a drop in transpiration under terminal stress. Shamsi *et al.* (2010) reported that in treatments involving irrigation, specifically one irrigation at the 50% flowering stage (I1) and another at the pod-filling stage (I2), the chickpea crop exhibited a notable increase in plant height, the number of axillary branches and the distance to the first pod from the soil surface, all of which were significantly higher compared to the irrigated control (I0). Sharma *et al.* (2007a) concluded that moisture stress significantly reduced the plant height of chickpea plants over the irrigated control. Sharma *et al.* (2007b) reported significantly taller plants in K 850 followed by Amethyst and the plants of C 214 were dwarfest among all the tested genotypes. The biomass accumulation was recorded highest in Annigeri followed by K 850 but with non-significant differences.

B) Root growth

Deep roots are a vital component determining the plant's ability to take water from deeper layers of the soil under moisture stress circumstances (Franco *et al.,* 2011). According to Miyahara *et al.* (2011), drought stress has been observed to elevate the count of lateral and fine roots in various crop species. This phenomenon not only enhances the root surface area, facilitating improved water absorption, but also augments root hydraulic conductivity. Purushothaman *et al.* (2017) concluded that drought condition increased root length density (RLD) below 30 cm soil depth and deep root bio-mass (RDW) but decreased the root diameter (RD) of chickpea. Kumar *et al.* (2018) concluded that under both irrigated and drought stress conditions, the rooting depth and shoot length of chickpea were lower in the drought-tolerant genotype RSG 931 compared to the drought-sensitive genotype HC-1. The percentage increase in rooting depth was higher in HC-1 (12.8%) than in RSG 931 (9.2%) under drought stress. While the roots' dry weight increased by 23% in the drought-tolerant RSG 931, it increased by 11.8% in the drought-sensitive HC-1 under drought stress conditions. The root-to-shoot ratio of the drought-tolerant genotype RSG 931 in chickpea was higher (0.80) under drought stress conditions compared to irrigated conditions (0.63). In an another experiment, Kumar *et al.* (2012) concluded that in rainfed conditions, the rooting depth of chickpea consistently surpassed that of the irrigated environment. At the full bloom stage under rainfed conditions, the roots exhibited penetration to a maximum depth ranging from 92 to 122 cm. The imposition of moisture stress led to an elevated biomass partitioning towards the roots, resulting in an increased root-to-shoot ratio, as well as higher dry weights observed for the stem, leaf, nodules and total dry weight per plant. Under rainfed conditions, genotypes ICCV-4958 and HC-5 exhibited higher dry weight of stem, leaves, roots, nodules, total dry weight per plant, rooting depth and root to shoot ratio compared to other genotypes. The root biomass per plant was greater in ICCV-4958 (6.7 g) and chickpea roots reached a minimum depth of 92 cm in CSJ-379 and a maximum of 122 cm in ICCV-4958 under rainfed conditions. Meanwhile, under irrigated conditions, chickpea roots achieved a maximum depth of 99 and 97 cm in HC-5 and ICCV-4958, respectively. At full bloom, approximately 29% and 33% of the total dry matter was allocated to the roots of HC-5 and ICCV-4958, respectively, under rainfed conditions. Kumar *et al.* (2010) concluded that in rainfed conditions, the rooting depth exhibited sustained elevation, with roots reaching a maximum depth ranging from 80 to 121 cm during the full bloom stage, surpassing levels observed in irrigated conditions. Notably, under rainfed conditions, moisture stress led to a reduction in plant height, while conversely, root depth experienced an increase, accompanied by a notable enhancement in biomass partitioning towards the roots. In rainfed conditions, the roots of HC-5 and H 02-36 penetrated the soil to a depth exceeding 100 cm, while H 04-33 roots were limited to 80 cm. Conversely, under irrigated conditions, HC-5 and H 02-36 reached maximum depths of 108 cm and 87 cm, respectively. HC-5 and H 02-36 exhibited the highest root biomass per plant, whereas H 04-31 and H 04-33 had the lowest. During full bloom, approximately 34% of the total dry matter was allocated to the roots of HC-5, with slightly higher values (39%) in H 02-36 under rainfed conditions. Parameshwarappa *et al.* (2010) observed that chickpea genotypes characterized by deep and dense root systems exhibit enhanced drought tolerance by effectively extracting water from deeper soil layers. The augmentation of root length, root weight and root volume corresponds to an increase in grain yield, particularly under conditions of terminal drought. Macar *et al.* (2009) found that under drought conditions, the shoot-to-root ratio in chickpea experiences a decrease attributed to a reduction in epicotyl elongation compared to root

growth. A diminished rate of root growth serves as a reliable indicator of the drought susceptibility of cultivars. Singh and Singh (2006) reported that water stress affects nodule formation in plants, because glucose transport from leaves to nodules is restricted.

C) Biomass partitioning

The impact of moisture stress was evident in the substantial reduction of plant height in chickpea plants, while conversely, root depth experienced a notable increase. During the full bloom stage, there was a distinct biomass allocation pattern, with roots, leaves and stem contributing 20.78%, 33.15% and 37.24% of the total biomass, respectively. Mild moisture stress demonstrated no discernible impact on biomass partitioning in chickpea, whereas under severe moisture stress conditions, there was a notable reduction in the allocation of biomass to seeds, pods and roots, despite an increase in root length compared to the irrigated control. Among different chickpea genotypes, PUSA-1103 exhibited the tallest plants at full bloom stage, followed by BGD-72. However, the roots of PUSA-1053, PUSA-1103 and PUSA-362 were statistically comparable and penetrated significantly deeper into the soil profile than the roots of other genotypes at full bloom stage. The percentage of total dry matter accumulation in stem, leaves and roots was higher in PUSA-1103, PUSA-1053, PUSA-1108 and PUSA-362 (Singh *et al.,* 2010). The dry biomass reduction in water stressed plants could be attributed to lower CO2 accumulation in biochemical reactions of photosynthesis and therefore to lower carbohydrates production.

Effect of irrigation levels and genotypes on the yield attributes and yield of chickpea

Arif *et al.* (2021) concluded that the most suitable chickpea genotypes for cultivation in non-stressed conditions were CH39/08, CH40/09 and CH15/11, while CH28/07 and CH39/08 were identified as suitable for both stressed and non-stressed environments. CH 55/09 exhibited optimal yield performance specifically in stress conditions. Mohammed *et al.* (2020) found that chickpea variety Minjar recorded highest yield, which produced 3349.9 kg ha^{-1} of seed, followed by Dimtu (3218.9 kg ha^{-1}) and Mitik (2763.2 kg ha^{-1}), respectively under irrigated conditions. Seed yield per plant and 100 seed weight of chickpea were significantly higher for Mastewal variety, while number of pods per plant, number of seeds per pod and harvest index was significantly greater for Habru variety as reported by Mekonnen (2020). Sarkar and Sarkar (2019) reported that chickpea crop, when irrigated with an IW/CPE of 0.6, demonstrated a superior yield, recording 7.14% and 23.53% higher seed production compared to the chickpea crop irrigated with an IW/CPE of 0.4 (yielding 0.98 t ha^{-1}) and the rainfed scenario (yielding 0.85 t ha^{-1}), respectively.

Singh *et al.* (2017) reported that the provision of two supplemental irrigations to chickpea at the pre-flowering and pod formation stages resulted in a notable increase in the number of pods per plant, the number of seeds per pod and seed yield in comparison to situations with no irrigation. Similarly, in Hisar region, Reeta (2019) found that in the irrigated environment, characterized by the application of two irrigations at the pre-flowering stage and pod development stage, the yield attributing characters and overall yields demonstrated a noteworthy increase compared to the rainfed environment. Kumar *et al.* (2018) found that the seed yield of both chickpea genotypes HC-1 and RSG 931 declined under drought stress conditions, with RSG 931 experiencing a lower decrease (25.8%) compared to HC-1 (47%). Muruiki *et al.* (2018) observed variations in seed yield among different chickpea varieties under conditions of moisture stress, with maximum yield in ICCV 92944 (1173 kg ha^{-1}) followed by ICCV 92318 (1103 kg ha^{-1}), CAVIR (975 kg ha^{-1}), ICCV 92318 (967 kg ha^{-1}), ICCV 00108 (956 kg ha^{-1}) and ICC 4958 (921 kg ha^{-1}). Under drought conditions, Brahmane *et al.* (2017) found that the chickpea genotypes Digvijay, Vishal and Vijay were proven to be superior in terms of yield and yield contributing qualities.

Pang *et al.* (2017) found that withholding water from early podding lowered vegetative and reproductive growth, seed production, seed yield and water use efficiency in chickpea genotypes. The occurrence of early podding in chickpea genotypes, induced by terminal moisture stress, led to a decline in biomass, reproductive development, harvest index and seed yield. As the drought advanced, the percentage of floral abortion, pod abscission and empty pods nearly doubled. When water was withheld from flowering till harvest, Khoiwal *et al.* (2017) found the highest seed yield in chickpea genotype JG 16 followed by JG 130 and JG 11 under the moisture stress conditions. Chourasiya *et al.* (2016) observed that chickpea cultivation with irrigation applied at branching and pod development stages resulted in a significantly higher seed yield of 1483.33 kg ha^{-1}. The increment in seed yield achieved with irrigation at branching and pod development stages surpassed that of irrigation at pod development alone and irrigation at branching alone by 11.12% and 14.22%, respectively. The application of irrigation to the chickpea crop during the vegetative stage led to a notable enhancement in both above-ground biomass and grain yield, registering increases of 59% and 36%, respectively. Singh *et al.* (2016) reported that in comparison to no irrigation, the application of 75 mm of irrigation during the vegetative stage and both the vegetative and podding stages resulted in significant increases in grain production, specifically by 59% and 73%, respectively in first year of study and 7% and 27% respectively in the second year of study. However, these irrigation practices had minimal effects on water productivity based on irrigation and rainfall (WPI+R). Improvement of soil-moisture status in the root zone of a crop through irrigation favored the growth and development of the plant and thus, increased the height, dry matter and yield attributing characters which induces better biological yield (Sarkar *et al.,* 2016).

Alla Jabow *et al.* (2015) found that the influence of irrigation regimes was pronounced in terms of the number

of pods per plant, number of seeds per pod, 100-seed weight, grain yield and the total irrigation water applied. Optimal values for these parameters were observed under full irrigation, while the most significant reduction occurred under conditions of acute water stress. Comparative analysis with full irrigation revealed that moderate and severe water stress regimes resulted in water savings of 24% and 32%, respectively. Rajkumara *et al.* (2014) reported that irrigating chickpea at 0.8 IW/CPE ratio significantly increased the chickpea seed yield in *rabi* season crop. Swarup and Holkar (2014) concluded that chickpea genotype IG 370 demonstrated superior moisture stress tolerance, yielding 1674 kg ha^{-1}, outperforming late-maturing genotypes (IG 226, KAK 2 and IG 592). Additionally, genotypes such as Vishal, IG 592, JG 412 and Ujjain 21 exhibited minimal yield reduction under drought stress, indicating high drought tolerance efficiency.

Randhawa *et al.* (2014) concluded that the key yield attributes, including 100-seed weight, total number of pods and the percentage of filled pods, experienced significant decreases in response to water stress. The grain yield exhibited substantial reductions under restricted irrigation conditions, ranging from 40.50% to 55.91% from treatment T_4 (withholding irrigation at the pod-initiation stage) to T_2 (one pre-sowing irrigation), compared to the irrigated control (T_1). GL 28151, RSG 963 and PDG 3 emerged as resilient chickpea genotypes, displaying superior yield and associated attributes (100 seed weight, total number of pods and percentage filled pods) under water stress conditions. Conversely, GL 22044, RSG 1861 and RVSSG 4 exhibited a negative impact on yield and associated attributes in response to water stress. Ghassemi-Golezani *et al.* (2013) reported that the impact of water stress on seed output is manifested through a reduction in the number of pods per plant, the number of seeds per plant, 100-seed weight, biological yield, seed yield and harvest index of chickpea. Number of pods under moisture stress reduced mainly due to an increased rate of floral and pod abortion and detrimental effects of drought avoidance on CO_2 assimilation. The degree of influence is contingent on the severity of drought and the tolerance level of the cultivar.

Ulemale *et al.* (2013) found that under irrigated conditions, the chickpea genotypes Phule G 07101, Phule G 2008-74, Digvijay and Phule G 0302-26 were ideal for yield and yield contributing characters, while under drought conditions, the chickpea genotypes Phule G 09103, Phule G 2008-74, Digvijay and Phule G 0302-26 were promising for yield and yield components characters. Biradar *et al.* (2013) conducted an experiment by using sixteen chickpea genotypes under rainfed condition and found that BG-1092 recorded significantly higher yield (1599 kg ha^{-1}) followed by ICC-4958 (1279 kg ha^{-1}). Kumar *et al.* (2012) observed the highest seed yield per plant, reaching 15.6 g and 14.7 g per plant, respectively, in the chickpea genotypes ICCV-4958 and HC-5 under rainfed conditions. Hirich *et al.* (2011) reported that chickpea plants subjected to drought stress during the vegetative period exhibited the highest yield, reaching 6.5 t ha^{-1}, surpassing the yield obtained for the control, which was 4.9 t ha^{-1}. Shamsi *et al.* (2010) and Singh *et al.* (2010) reported that the grain yield, number of grains per plant, number of pods per plant, biological yield, harvest index and 100-grain weight of chickpea were markedly higher under irrigated treatment compared to conditions of drought stress. The highest pod density and 100 seed weight were observed in PUSA-1103, while the highest seeds per pod were recorded in PUSA-1105 and PUSA-372. PUSA-1103 exhibited the maximum biomass, seed yield and harvest index, which was statistically at par with BGD-72 and significantly higher than all the other tested genotypes. Mafakheri *et al.* (2010) concluded that under drought conditions, the drought-tolerant variety Bivaniej exhibited the highest yield, while the drought-sensitive variety Pirouz showed the lowest yield. Drought stress during the anthesis phase had a more severe impact on seed yield compared to stress during the vegetative stage. Haque *et al.* (2010) concluded that drought had a substantial impact on seed output in chickpea genotypes. Kumar *et al.* (2010) recorded highest seed yield per hectare in chickpea genotypes Pusa-72, KGD-1174 and Pusa-1053. The genotypes HC-5 and H 02-36, characterized by a deep root system, demonstrated elevated shoot biomass production, measuring 9.5 and 7.7 g/plant, along with substantial seed yield of 16.9 and 14.2 g/plant, respectively, under rainfed conditions.

Sharma *et al.* (2007a) concluded that the number of effective pods per plant, 100 seed weight, seed output, biological yield and harvest index were all significantly lowered by moisture stress in chickpea crop as compared to irrigated control. Significantly higher 100 seed weight and biological yield was observed in ICC 4958 and highest seed yield per plant in ICCV 10 as compared to other genotypes under trial. Sharma *et al.* (2007b) reported that due to terminal moisture stress, the seed yield was reduced by 33.3 and 13.2 per cent in severely stressed rainout shelter and mildly stressed rainfed treatment over irrigated control. Nayyar *et al.* (2006) found that flowering and pod setting in chickpea appear to be the most drought-sensitive stages. Due to photosynthetic limits caused by water stress during flowering and grain filling, grain yields of chickpea crop were reduced by 50-80 per cent.

CONCLUSION

Different irrigation regimes, including varying frequencies and amounts of water application, can affect the growth, development and yield of chickpea plants. Optimal irrigation management, providing sufficient moisture at the right time can promote vigorous growth, improved pod formation, higher seed set and increased yield potential. To overcome the yield reductions from terminal drought, chickpea is grown with supplemental irrigation in some part of the world, particularly in west Asia and northern India. However, the actual number of irrigations required depends upon many

factors including the rainfall received, soil texture, weather conditions and crop duration. Also, the chickpea genotypes vary in their genetic makeup, physiological traits and adaptability to different environmental conditions. Some genotypes may exhibit inherent tolerance to water stress or drought conditions, allowing them to maintain growth and productivity even with limited water supply. Other genotypes may be more sensitive to water stress, showing reduced growth and lower yield under drought conditions. Thus, selecting suitable chickpea genotypes with traits such as drought tolerance, early maturity and high yield potential can help mitigate the adverse effects of water stress and optimize productivity in different growing environments. The complex interaction between irrigation levels and chickpea genotypes can influence plant response to water application and overall yield performance. Thus, a thorough understanding of variety/genotype selected and its critical stages of irrigation is essential to improve chickpea productivity and water use efficiency so that farmers can ensure sustainable crop production in diverse agro-climatic conditions.

Conflict of interest

There is no conflict of interest.

REFERENCES

Alla Jabow, M.K., Ibrahim, O.H. and Adam, H.S. (2015). Yield and water productivity of chickpea (*Cicer arietinum* L.) as influenced by different irrigation regimes and varieties under semi desert climatic conditions of Sudan. *Agricultural Sciences*. **6:** 1299-1308.

Anonymous (2022). Department of Economics and Statistics, Ministry of Agriculture Cooperation and Farmers Welfare, Government of India.

Arif, A., Parveen, N., Waheed, M.Q., Atif, R.M., Waqar, I. and Shah, T.M. (2021). A comparative study for assessing the drought-tolerance of chickpea under varying natural growth environments. *Frontiers in Plant Science*. **11:** 607-869. doi: 10.3389/fpls.2020.607869.

Basu, P.S., Ali, M. and Chaturvedi, S.K. (2007). Osmotic adjustment increases water uptake, remobilization of assimilates and maintains photosynthesis in chickpea under drought. *Indian Journal of Experimental Biology*. **45:** 261-267.

Biradar, S.R., Patil, D.P., Ravi, Kumar, V.C. and Khoti, R.V. (2013). Morphological and agronomic responses to drought stress of chickpea genotypes under rainfed condition. *International Journal of Agricultural and Statistical Sciences*. **9(1):** 221-227.

Brahmane, R.O., Bharud, R. and Deshmukh, D. (2017). Study of growth and yield variation of chickpea genotypes under moisture stress condition. *International Journal of Genetics*. **9(4):** 266-270.

Chandler, J.N. and Bartels, D. (2008). Drought: Avoidance and Adaptation. In: Encyclopedia of Water Science. [Trimble, S.W., Stewart, B.A. and Howel, T.A. (eds)], Taylor and Francis Group, London. pp. 224.

Chauhan, J.S., Singh, B.B. and Gupta, S. (2016). Enhancing pulses production in India through improving seed and variety replacement rates. *Indian Journal of Genetics and Plant Breeding*. **76(4):** 1-10.

Chourasiya, A., Naik, K.R., Chauhan, A. and Das, S. (2016). Impact of land configurations, irrigation scheduling and weed management on yield and economics of chickpea (*Cicer arietinum* L.). *International Journal of Agricultural Science*. **8:** 2180-2181.

Dhaka, A.K., Kumar, S., Dhaka, P., Jat, R.D. and Singh, B. (2023). Biomass partitioning, yield and economic performance of green gram (*Vigna radiate* L.) genotypes as influenced by different irrigation levels. *Environment Conservation Journal*. **24(3):** 174-185.

Dhaka, A.K., Jat, R.D., Singh, B., Dhaka, P., Kumar, S. and Kumar, S. (2024). Relative yield, competition, land use and economic performance of chickpea-based intercropping systems. *Legume Research-An International Journal*. doi: 10.18805/LR-5141.

Dharanguttikar, V.M., Bharud, R.W. and Borkar, V.H. (2015). Physiological responses of chickpea genotypes for drought tolerance under induced moisture stress. *International Journal of Scientific and Research Publications*. **5(9):** 23-26.

Dhima, K., Vasilakoglou, I., Stefanou, S. and Eleftherohorinos, I. (2015). Effect of cultivar, irrigation and nitrogen fertilization on chickpea (*Cicer arietinum* L.) productivity. *Agricultural Sciences*. **6:** 1187-1194.

Franco, J.A., Banon, S., Vicente, M.J., Mirales, J. and Martinez-sanchez, J.J. (2011). Root development in horticultural plants grown under abiotic stress conditions- A review. *The Journal of Horticultural Science and Biotechnology*. **86(4):** 543-556.

Ghassemi-Golezani, K., Ghassemi, S. and Bandehhagh, A. (2013). Effects of water supply on field performance of chickpea (*Cicer arietinum* L.) cultivars. *International Journal of Agronomy and Plant Production*. **4(1):** 94-97.

Halagalimath, S.P. and Rajkumara, S. (2018). Response of chickpea (*Cicer arietinum* L.) varieties to irrigation and hydrogel application in Vertisols. *Legume Research-An International Journal*. **41(2):** 259-262. doi: 10.18805/LR-3735.

Haque, M., Pathak, M., Ansari, N.A., Srivastava, S. and Tewari, J.P. (2010). Effect of water stress on growth and seed yield of different varieties of chickpea (*Cicer Arietinum* L.). *International Journal of Plant Science.* **5(1):** 38-39.

Harish, D., Bharadwaj, C., Kumar, T., Patil, B.S., Pal, M., Hegde, V.S. and Sarker, A. (2020). Identification of stable drought tolerant landraces of chickpea (*Cicer arietinum*) under multiple environments. *The Indian Journal of Agricultural Sciences*. **90(8):** 1575-1581.

Hirich, A., Choukr-allah, R., Jacobsen, S.E., Hamdy, A., Elyoussfi, L. and El-Omari, H. (2011). Improving water productivity of chickpea by the use of deficit irrigation with treated domestic wastewater. *World Academy of Science, Engineering Technology*. **59:** 1352-1357.

Kamal, Dhaka, A.K., Singh, B., Kamboj, E., Preeti and Sharma, A. (2024). Effect of phosphorus and sulphur levels on biomass partitioning in groundnut (*Arachis hypogaea* L.). *Research on Crops*. **25(1):** 57-64. doi:10.31830/2348-7542.2024.ROC-1031.

Kamal, Kamboj, E., Sharma, A., Ravi, Dhaka, B.K. and Preeti (2023). Effect of phosphorus application on groundnut (*Arachis hypogaea* L.): A review. *International Journal of Plant and Soil Science*. **35(18):** 1536-1544. doi:10.9734/ijpss/2023/v35i183423.

Kamboj, E. (2022). Evaluation of chickpea genotypes under different irrigation levels. Ph.D. Thesis, Department of Agronomy, CCS Haryana Agricultural University, Hisar, India.

Kamboj, E., Kumar, S. and Dhaka, A.K. (2021). Effect of Irrigation levels and genotypes on growth indices of chickpea (*Cicer arietinum* L.). *Frontiers in Crop Improvement*. **9(Special Issue-VII):** 2871-2874.

Karim, A.N.M.A., Sarker, U.K., Hasan, A.K., Islam, N. and Uddin, M.R. (2021). Selection of drought tolerant high yielding chickpea genotypes based on field performance and genetic variation in Bangladesh. *Legume Research-An International Journal*. **44(10):** 1131-1137. doi: 10.18805/LR-629.

Khamssi, N.N., Golezani, K.G., Najaphy, A. and Zehtab, S. (2011). Evaluation of grain filling rate, effective grain filling period and resistance indices under acclimation to gradual water deficit stress in chickpea cultivars. *Australian Journal of Crop Science*. **5(6):** 1044-1049.

Khoiwal, S., Solanki, R. and Jain, M. (2017). Evaluation of chickpea varieties under different moisture stress condition on growth and yield of chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences*. **6(6):** 272-278.

Kumar, N., Nandwal, A.S., Devi, S., Sharma, K.D., Yadav, A. and Waldia, R.S. (2010). Root characteristics, plant water status and CO_2 exchange in relation to drought tolerance in chickpea. *Journal of SAT Agricultural Research*. **8:** 1-5.

Kumar, N., Nandwal, A.S., Waldia, R.S., Singh, S., Devi, S., Sharma, K.D. and Kumar, A. (2012). Drought tolerance in chickpea as evaluated by root characteristics, plant water status, membrane integrity and chlorophyll fluorescence techniques. *Experimental Agriculture*. **48(3):** 378-387.

Kumar, P., Boora, K.S., Kumar, N., Batra, R., Goyal, M., Sharma, K.D. and Yadav, R.C. (2018). Traits of significance for screening of chickpea (*Cicer arietinum* L.) genotypes under terminal drought stress. *Journal of Agrometeorology*. **20(1):** 40-45.

Kumar, P.R., Mali, S.S., Singh, A.K. and Bhatt, B.P. (2021). Impact of irrigation methods, irrigation scheduling and mulching on seed yield and water productivity of chickpea (*Cicer arietinum*). *Legume Research-An International Journal*. **44(10):** 1247-1253. doi: 10.18805/LR-4188.

Macar, T.K., Turan, O. and Ekmekc, Y. (2009). Effects of water deficit induced by PEG and NaCl on chickpea (*Cicer arietinum* L.) cultivars and lines at early seedling stages. *Gazi University Journal of Science*. **22:** 5-14.

Mafakheri, A., Siosemardeh, A., Bahramnejad, B., Struik P.C. and Sohrabi, Y. (2010). Effect of drought stress on yield, proline and chlorophyll contents in three chickpea cultivars. *Australian Journal of Crop Science*. **4(8):** 580-585.

Mekonnen, L. (2020). Effects of water stress applied at different phenological phases of chickpea (*Cicer arietinum* L.). *International Journal of Agricultural Research Innovation and Technology*. **10(1):** 13-21.

Miyahara, M., Takenaka, C., Tomioka, R. and Ohta, T. (2011). Root responses of Siberian larch to different soil water conditions. *Hydrological Research Letter*. **5:** 93-97. http://dx.doi.org/10.3178/hrl.5.93.

Moemeni, F, Ghobadi, M., Jalali-Honarmand, S. and Shekaari, P. (2013). Effect of supplementary irrigation on growth analysis of chickpea (*Cicer arietinum* L.). *International Journal of Agriculture and Crop Sciences*. **5(14):** 1595-1600.

Mohammed, A., Bisetegn, S., Misganaw, A., Desale, A. and Alemnew, T. (2020). Evaluation of desi type chickpea varieties for adapting under irrigation at Kobo. *Agrotechnology*. **9:** 200. doi: 10.35248/2168-9881.20.9.200.

Muruiki, R. and Kimurto, P. and Vandez, V. and Gangarao, N.V.P.R., Silim, S. and Siambi, M. (2018). Effect of drought stress on yield performance of parental chickpea genotypes in semi-arid tropics. *Journal of Life Sciences*. **12(3):** 159-168.

Nayyar, H., Singh, S., Kaur, S., Kumar, S. and Upadhyaya, H.D. (2006). Differential sensitivity of macrocarpa and microcarpa types of chickpea (*Cicer arietinum* L.) to water stress: Association of contrasting stress response with oxidative injury. *Journal of Integrative Plant Biology*. **48:** 1318-1329.

Pang, J., Turner, N.C., Du, Y., Colmer, T.D. and Siddique, K.H.M. (2017). Pattern of water use and seed yield under terminal drought in chickpea genotypes. *Frontier in Plant Science*. **9(8):** 1375.

Parameshwarappa, P., Salimath, P., Upadhyaya, H.D., Patil, S.S., Kajjidoni, S.T., Patil, B.C. and Narayana, Y.D. (2010). Variation in root characters of selected drought tolerant accessions of chickpea (*Cicer arietinum* L.) grown under terminal drought. *Karnataka Journal of Agricultural Sciences*. **25(3):** 389-391.

Pawar, D.D., Dingre, S.K., Nimbalkar, A.L. (2013). Influence of different irrigation scheduling and land configurations on growth and yield of chickpea. *Journal of Agriculture Research and Technology*. **38(1):** 107-112.

Purushothaman, R., Krishnamurthy, L., Upadhyaya, H.D., Vadez, V. and Varshney, R.K. (2017). Root traits confer grain yield advantages under terminal drought in chickpea. *Field Crops Research*. **20:** 146-161.

Rajkumara, S., Gundlur, S.S., Neelakanth, J.K. and Ashoka, P. (2014). Impact of irrigation and crop residue management on maize (*Zea mays* L.)-chickpea (*Cicer arietinum* L.) sequence under no tillage conditions. *Indian Journal of Agricultural Sciences*. **84(1):** 43-48.

Randhawa, N., Kaur, J., Singh, S. and Singh, I. (2014). Growth and yield in chickpea (*Cicer arietinum* L.) genotypes in response to water stress. *African Journal of Agricultural Research*. **9(11):** 982-992.

Reeta. (2019). Agro-physiological evaluation of chickpea (*Cicer arietinum* L.) genotypes under soil moisture stress. Thesis (M.Sc. Agronomy), Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Sachdeva, S., Bharadwaj, C., Patil, B.S., Pal, M., Roorkiwal, M. and Varshney, R.K. (2022). Agronomic performance of chickpea affected by drought stress at different growth stages. *Agronomy*. **12(5):** 995.

Sarkar, S. and Sarkar, A. (2019). Role of irrigation and mulch in chickpea (*Cicer arietinum* L.) growth, productivity and moisture extraction pattern in alluvial zone of West Bengal, India. *Legume Research-An International Journal*. **42(1):** 77-83. doi: 10.18805/LR-3815.

Sarkar, S., Sarkar, A. and Zaman, A. (2016). Yield, water use and economics of chickpea (*Cicer arietinum*) as influenced by different levels of irrigation and mulches. *Indian Journal of Agronomy*. **61(4):** 479-483.

Shamsi, K., Kobraee, S. and Haghparast, R. (2010). Drought stress mitigation using supplemental irrigation in rainfed chickpea (*Cicer arietinum* L.) varieties. *African Journal of Biotechnology*. **9(27):** 4197-4203.

Sharma, K.D., Pannu, R.K. and Singh, D.P. (2007a). Water use efficiency and yield of chickpea genotypes as influenced by soil moisture availability. *Indian Journal of Plant Physiology*. **12(2):** 168-172.

Sharma, K.D., Pannu, R.K., Tyagi, P.K., Chaudhary, B.D. and Singh, D.P. (2007b). Response of chickpea genotypes to plant water relations and yield under soil moisture stress. *Journal of Agrometeorology*. **9(1):** 42-48.

Sihag, R., Kumar, P., Singh, K., Kumar, J. and Kumar, A. (2019). Growth and productivity of chickpea genotypes under different soil moisture environment. *Indian Journal of Agricultural Research*. **53(6):** 708-712. doi: 10.18805/IJARe.A-5336.

Singh, A.K., Singh, S.B., Singh, A.P., Singh, A.K., Mishra, S.K. and Sharma, A.K. (2010). Effect of different soil moisture regimes on biomass partitioning and yield of chickpea genotypes under intermediate zone of J and K. *Journal of Food Legumes*. **23(2):** 156-158.

Singh, B. and Singh, G. (2006). Effects of controlled irrigation on water potential, nitrogen uptake and biomass production in *Dalbergia sissoo* seedlings. *Environmental and Experimental Botany*. **55:** 209-219.

Singh, G., Ram, H., Aggarwal, N. and Turner, N.C. (2016). Irrigation of chickpea (*Cicer arietinum* L.) increases yield but not water productivity. *Experimental Agriculture*. **52(1):** 1-13. doi: 10.1017/S0014479714000520.

Singh, R., Kumar, S., Kumar, H., Kumar, M., Kumar, A. and Kumar, D. (2017). Effect of irrigation and integrated nutrient management on growth and yield of chickpea (*Cicer arietinum* L.). *Plant Archives*. **17(2):** 1319-1323.

Swarup, I. and Holkar, S. (2014). Physiological and yield performance of chickpea genotypes under drought stress. Indian *Journal of Dry land Agriculture Research and Development*. **29(1):** 23-26.

Tiwari, S., Thakur, H.S. and Girothia, O.P. (2018). Effect of moisture stress and non-stress condition on phenological character for drought tolerance of different chickpea (*Cicer arietinum* L.) varieties. *International Journal of Chemical Studies*. **6(6):** 2275-2278.

Ulemale, C.S., Mate, S.N. and Deshmukh, D.V. (2013). Physiological indices for drought tolerance in chickpea (*Cicer arietinum* L.). *World Journal of Agricultural Sciences*. **9(2):** 123-131.

Vishnu, B., Jayalakshmi, V. and Rani, M.S. (2020). Genetic diversity studies among chickpea (*Cicer arietinum* L.) genotypes under rainfed and irrigated conditions for yield attributing and traits related to mechanical harvesting. *Legume Research-An International Journal*. **43(2):** 190-194. doi: 10.18805/LR-3959.

Yücel, D. (2018). Response of chickpea genotypes to drought stress under normal and late sown conditions. *Legume Research-An International Journal*. **41(6):** 885-890. doi: 10.18805/LR-434.

Zaman-Allah, M., Jenkinson, D.M., Vadez, V. (2011). Chickpea genotypes contrasting for seed yield under terminal drought stress in the field differ for traits related to the control of water use. *Functional Plant Biology*. **38(4):** 270-281.