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Drought stress management in Chickpea at various growth stages through the foliar application of plant extracts and growth regulators

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A research investigation was attempted to explore the impact of plant extracts Moringa leaf extract (*Moringa oliefera L*) and Iple leaf extract (*Leucaena levcocephala)* @ 3% and synthetic plant growth regulators (Amino acid @ 20% and Potassium sulfate @ 5%) on the growth and yield of chickpea under drought conditions at the Arid Zone Research Centre, Dera Ismail Khan, during the rabi season of 2019-20. The research field was laid out in an RCBD design with a split-plot arrangement with three repetitions. Main plots were comprised of three stages (vegetative stage, flowering stage, and pod initiation), and sub-plots were comprised of plant extracts and plant growth regulators. Data on different morphological, physiological, and yield-contributing aspects were recorded. Nodules plant^{-1} (No.) 60.66, nodules fresh weight plant^{-1} (4.80 g), nodules dry weight plant^{-1} (2.15 g), pods plant^{-1} (No.) 62.33, grains pod^{-1} (No.) 2.30, 100 grain weight (15.18 g), and grain yield (1876 kg ha^{-1}) were all much higher in all three stages when potassium sulfate @ 5% was used. K_2SO_4 appeared as the most effective treatment, offering superior outcomes as compared to Moringa leaf extract and Iple in terms of enhancing growth, development, and yield. However, the shortest span of flowering was observed in moringa sprayed after 80 days after the emergence of the crop. Moringa leaf extract has demonstrated some effectiveness, and its organic characteristics and lack of long-term effects make it a desirable option for sustainable farming. However, its usefulness may not match that of commercial PGRs in terms of enhancing plant growth and yield. The method of application and concentrations of plant extracts need further investigation to enhance their effectiveness on crop growth and development.

Keywords: Moringa leaf extract, Iple, Potassium sulfate, Growth regulators.

INTRODUCTION

Chickpea (*Cicer arietinum* L) is the basic diet item in several countries in globe and is normally cultivated as pre winter crop. Change in current climate resulted change in temperature and precipitation profiles, leading to intense drought condition. This fluctuation in ecological condition resulted an increase in global warming which in turn resulted an increase in demand for irrigation. (Khan et al. 2018). On the other hand, rise in population resulted severe devastation of prime cropland due to increase in soil erosion and urbanization. Therefore, there is need to utilize soils with minimal ability for crop growth and production (Vymazal, 2007) Clay loam soils are poorer in plant growth and have less fertility status due to its capability and however, the fertility and yield capabilities of these soils can be improved with the application of compost leaf mould, manure or by the application of Plant growth promoters. Chickpea boast up soil fertility due to its nitrogen fixing capability and important source of protein (Maiti, 2001). There is an increasing demand for improving tolerance in pulses especially in chickpea against drought, in order to fulfill the world food demand. Thus, policies may be developed to accomplish crops plants against drought stress and to develop drought tolerance in crop plants (Venkateswarlu et al. 2009). In our country soil fertility, food security and most importantly protein deficiency in diet are burning issues.

Plant growth promoters are substances that influence the growth and development of plants. PGR also plays a significant role in the plant developmental process and thus modulates plant responses to abiotic stresses. They have been found to improve the damage caused by abiotic stresses. Salicylic acid (SA) is known for its defensive role when present in plants at an appropriate concentration. SA was shown to be responsible for drought tolerance in plants (Singh et al. 2003)**.** Foliar spray of SA repairs the negative effects of drought and increases the restoration process in plants. Plant growth promoters result in an increase in growth rate and seedling emergence and improve the responses of plants to various stimuli and plant pathogens. Plant growth promoters induce an increase in the development and yield of crops, which has been confirmed in field trials (Gravel et al. 2007)**.** They were also stimulatory to the growth and yield of rice, radish, sugar beet, potato, apple, tomato, wheat, beans, and ornamental plants (Khalid et al. 2004).

Bio stimulants are natural crop growth promoters. Phytohormones not only increase crop yield and quality but also protect the plants against various abiotic stresses (European Bio stimulant Industry Council 2012). MLE, sorghum extract, and iple leaf extract are the most commonly used as plant growth regulators when applied as seed priming agents and foliar sprays because they positively modify plant growth and production (Rady et al. 2013; Yasmeen et al. 2013; Semida and Rady, 2014) under normal or stressful conditions. MLE has gained attention for its potential use in agriculture, including as a plant growth promoter. There are some ways in which Moringa leaf extract (MLE) may act as a plant growth promoter. Moringa leaves are rich in nutrients, including vitamins, minerals, and amino acids (Bakhtawar et al. 2015). Foliar application of MLE along with benzyl amino purine and hydrogen peroxide at critical stages of wheat enhances its growth and development, ultimately yield. (Yasmeen et al. 2013 b). The effectiveness of MLE as a bio stimulant is equal or greater than that of synthetic crop growth enhancers. On the other hand, MLE is cost-effective and environment-friendly. Foliar application of MLE alone or in blend with kinetin solution significantly improved the stand establishment parameters, increased chlorophyll contents, crop growth rate, photosynthetic rate, leaf area index, and yield of normal and late-sown maize crops. Moringa extracts have shown some antimicrobial properties, which could contribute to disease resistance in plants. Healthy plants are more likely to exhibit robust growth. (Bakhtavar et al. 2015).

MLE, exogenously applied either through seed or plant foliage, is considered to boost emergence, seedling growth, and growth in various field crops under normal as well as unfavorable conditions (Basra et al. 2011). Its application as seed priming reduced emergence time, enhanced germination rate, synchronized germination and crop establishment in wheat and rice (Farooq et al. 2008). Such enhancements in crop growth and development are associated with different physiological, biochemical, and agronomics attributes like greater leaf area, alteration in source sink relationship, delayed senescence, increased antioxidant activities, chlorophyll enhancement, ascorbic acid, and total phenolic contents, which play their roles in improving crop resistance against unfavorable conditions and ultimately increasing the economic outcome (Yasmeen et al. 2013a, b).

When used as a foliar spray or soil amendment, MLE can provide essential nutrients that promote plant growth. Some studies suggest that moringa extracts may contain compounds with hormonal activity, such as cytokinin’s and auxins. These compounds can influence cell division, shoot and root development, as well as overall plant growth. Moringa is known for its high antioxidant content. Antioxidants play a role in protecting plants from oxidative stress, which can enhance overall plant health and growth. Plant growth promoters not only support germination, flowering, and fruit development but also boost various physiological processes in plants. They have the utmost role in assimilation, translocation, preventing flower and fruit drop, and ultimately increasing yield. The present study was therefore aimed at evaluating the foliar application of plant extracts and synthetic plant growth promoters for effective chickpea production and optimizing the growth stage to get a higher chickpea yield under drought conditions.

MATERIALS AND METHODS

The experiment was planted using chickpea plants grown under wattar condition in the field. The crop was grown without any irrigation. The experiment was performed during the chickpea growing seasons 2019–20 at the Arid Zone Research Centre (AZRC), Dera Ismail Khan. The experiment was carried out in a Randomized Complete Block Design having arranged in split plots with three replications. Plot size 5 m × 2.5 m. We took 3 KG of fresh leaves of *Moringa oleifera* L. and *Leucaena leucocephala* and cleaned them with tap water. After properly cleaning, the leaves were kept for drying under shade for 10 days. The leaves were kept in the oven at 70 °C for 72 hours to properly dry. After drying, the leaves were grinded with the help of an electric grinder, and an aqueous extract was prepared by dissolving 25 grams of moringa and iple powder in 1000 ml of water. The aqueous extract was filtered through Whatman No. 1 filter paper. Plant growth promoters were applied at different growth stages, i.e., S_1 (vegetative stage), S_2 (flowering stage), and S_3 (pod initiation).

T_1	Moringa Leaf Extract (3%)
T_2	Iple Leaf Extract (3%)
T_3	Amino Acid (20%)
T_4	Potassium Sulfate (5%)
T_5	Control

Methods of data collection

Days to 50% flowering (No.)	It was visually observed that 50% of plants bore one flower.
Nodules plant^{-1} (No.)	The nodules of five plants were totaled before flowering in each plot, and then the average was calculated.
Nodules fresh weight plant^{-1}(g)	Fresh nodules of five randomly selected plants were digitally weighed before flowering.
Nodules dry weight plant^{-1}(g)	Dry weight of nodules was also recorded before flowering. Initially nodules were dried under the sun for two days, their further drying were performed in electric oven for 24 hours at 75ºC.
Plant height (cm)	Plant height was measured at physiological maturity.
Pod plant^{-1} (No.)	Plants were randomly selected and then their pods were counted and averaged.
Grains pod^{-1} (No.)	Grains of five randomly selected plants were counted and their average was used for explaining results after data analysis.
Sterility (%)	Sterility (%) were recorded by counting empty pods plant^{-1}.
100 grain weight (g)	100 grains were obtained from randomly selected plants and weighed.
Grain yield (kg ha^{-1})	Grain yield (kg ha^{-1}) = Grain yield kg m^{-2}× 10000
Biological yield (kg ha^{-1})	Biological yield (kg ha^{-1}) = Biological yield kg m^{-2}×10000
Harvest index (%)	Harvest index = (Grain yield / Biological yield) ×100

Statistical test used

The analysis of variance (ANOVA) techniques will be used for data collection (Steel et al. 1997) and comparison of individual treatment means were tested through $LSD_{0.05}$. Computer software "Statistix ver. 8.1" was used for statistical analysis.

RESULTS AND DISCUSSION

Days to 50% flowering

Flowerings indicate plants' reproductive ability during their life cycle. 50% flowering show significant results when using different plant growth promoters (Table 1). Treatments sprayed with potassium sulfate showed a maximum 50% flowering (114 days). The next maximum flowering days were noted in Iple leaf extract (109 days). Applying MLE led to the earliest flowering. Our results are in agreement with (Bahr, 2007) and (Mahmood et al. 2017) whose crops took the maximum days to flower when treated with foliar potassium sulfate. Insignificant averages were registered when these solutions were tested at different growth stages. All foliar applications at various growth stages the vegetative stage took minimum days to flowering (105.87 days) which is superior in all stages and maximum (110.87 days) were noted in S_3, followed by S_2 (110 days). Interaction also proved non-significant results statistically. The maximum days to flowering (121.00 days) were observed in combination with potassium sulfate applied at S_3 (Pod Initiation) Stage, followed by Iple leaf extract applied at S_3. However, the shortest span of flowering was observed in moringa sprayed at S_3 after after the emergence of the crop and amino acids (103.00 days), respectively. (Khan et al. 2019) proved early maturity in chickpea by applying moringa leaf extract. Early maturity provided ample time for grain filling in chickpea pods.

Number of nodules plant^{-1}

The results indicated a significant difference among the treatment means (Table 1). The maximum number of nodules (54.44) were counted in treatments treated with potassium sulfate followed by moringa leaf extract (50.66), whereas the minimum number of nodules (40.00) were counted in control. The maximum number of nodules in treatment applied with potassium sulfate could be due to the fact that the process of nodule formation usually starts after a month of sowing; at that time, the application of chemicals or phytoextracts seemed to be significant. phytoextracts and synthetic foliar application significantly enhanced the nodules per plant, as described by (Rafique et al. 2021) and (Chuhan et al. 2018). Growth stages also showed significant results, and the maximum number of nodules per plant (47.80) was counted at S_1 (vegetative stage), followed by 46.73 at S_3 (pod initiation), while the minimum (43.73) was counted in S_2 (flowering stage). The interaction between growth stages and various plant growth promoters proved to have non-significant results.

Table 1: Effect of plant growth promoters' applications at different growth stages of chickpea on days to 50% flowering (No.) and number of nodules plant^{-1} (No.).

Plant Growth Regulators	Days to 50% flowering (No.)				Nodules plant^{-1} (No.)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	104.00 ^{NS}	108.67	103.00	**105.22 b**	47.00 ^{NS}	53.00	52.00	**50.66 ab**
Iple leaf extract (3%)	104.67	109.33	113.67	**109.22 ab**	42.66	40.66	48.33	**43.88 bc**
Amino acid (20%)	106.67	111.67	103.00	**107.11 b**	45.00	39.00	40.33	**41.44 c**
Potassium sulfate (5%)	109.00	112.33	121.00	**114.11 a**	60.66	48.33	54.33	**54.44 a**
Control	105.00	108.00	111.67	**108.22 ab**	43.66	37.66	38.66	**40.00 c**
Means	**105.87 ^{NS}**	**110.00**	**110.47**		**47.80 a**	**43.73b**	**46.73a**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

The maximum number of nodules (60.66) was noted in potassium sulfate application at S_1 (vegetative stage), whereas minimum (37.66) was counted in the control plot at S_2 (flowering stage).

Nodules fresh weight plant^{-1} (g)

Statistical analysis showed significant differences in various plant growth promoters (Table 2). Among different exogenously applied solutions, the maximum nodules fresh weight (4.47 g) was recorded in potassium sulfate followed by iple leaf extract (3.68 g), whereas the minimum (3.17 g) was noted in control. (Rafique et al., 2021) found a significant relationship between nodules and their fresh weight. The time of application of these plant growth promoters at different growth stages and their interaction with the nature of plant growth promoters also remained non-significant. However, the visual differences found in interaction ranged from 3.00 to 4.80 (g). Growth stages showed non-significant results on nodules fresh weight of chickpea. Maximum nodule fresh weight (3.79 g) was recorded at S_2 (Flowering Stage), while minimum (3.43 g) was noted at S_3 (Pod Initiation). (Chauhan et al. 2018) obtained the best results for fresh weight of nodules at vegetative and flowering stage with the application of GA3, respectively. However, interaction showed maximum nodules fresh weight (4.80 g) was observed in S_2 (Flowering Stage) with potassium sulfate application, while minimum fresh weight (3.00 g) was recorded in control and S_3 (pod initiation).

Nodules dry weight plant^{-1}(g)

The data analysis declared significant results for various plant extracts and synthetic growth promoters on the dry weight of nodules (Table 2). The maximum nodules dry weight (g) was noted in potassium sulfate (1.99 g), followed by iple leaf extract (1.69 g), while the minimum dry weight of nodules was observed in amino acid (1.34 g). (Chovatia et al. 2010), (Vagner et al. 2013) and (Sharm and Jain, 2016) also confirmed our results. Non-significant results were recorded among different growth stages with the use of plant growth promoters. The maximum nodules dry weight (1.65 g) was recorded in S_1 (flowering stage). It was lowest (1.41 g) when foliar application was performed at S_3 (pod initiation). Interaction also remained non-significant. Maximum nodules dry weight was recorded in potassium sulfate (2.15 g) at S_2, followed by S_1 (2.05) in combination with potassium sulfate. The lowest dry weight (0.99 g) was observed in control treatments.

Table 2: Effect of plant growth promoters' applications at different growth stages of chickpea on nodule fresh weight plant^{-1} (g) and nodule dry weight plant^{-1} (g)

Plant Growth Regulators	Nodule fresh weight plant^{-1} (g)				Nodule dry weight plant^{-1} (g)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	3.31^{NS}	3.36	3.48	**3.38 b**	1.74 ^{NS}	1.73	1.45	**1.64 ab**
Iple leaf extract (3%)	3.76	4.03	3.27	**3.68 b**	1.75	1.7	1.62	**1.69 ab**
Amino acid (20%)	3.66	3.45	3.08	**3.39 b**	1.62	1.17	1.24	**1.34 b**
Potassium sulfate (5%)	4.18	4.80	4.34	**4.47 a**	2.05	2.15	1.77	**1.99 a**
Control	3.29	3.21	3.00	**3.17 b**	1.66	1.52	0.99	**1.39 b**
Means	**3.64 ^{NS}**	**3.79**	**3.43**		**1.65**	**1.41**	**1.41**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

Plant heig ht (cm)

The analyzed data regarding chickpea plant height (cm) as affected by different plant growth promoters applied at different growth stages revealed non-significant variations (Table 3). The use of various exogenously sprayed plant growth promoters significantly affected plant height. The maximum plant height (83.42 cm) was measured when plant growth promoters were applied at stage S_2, and the minimum (79.74 cm) plant height was measured in the S1 (vegetative stage) stage of the application of plant growth promoters. The use of various plant growth promoters also produced non-significant results for plant height. The maximum (82.32 cm) chickpea height was measured with foliar application of amino acid, followed by (81.68 cm) in iple leaf extract. The shortest (80.17 cm) plants were measured in controlled plots. The interaction of plant growth promoters and growth stages also gave non-significant results. Maximum tallness (86.76 cm) was registered by using amino acid applied at pod initiation, followed by moringa leaf extract (84.43 cm) applied at S_2 (flowering stage). Dwarf plants (76.16 cm) were obtained in control after. These non-significant results may be due to the use of a single chickpea cultivar (Indus 2019). However, the plant growth promoter's application also showed some improvement in plant height but was non-significant statistically. Results of (Taiz and Zeiger, 2003) confirmed that plant growth promoters are organic substances that, in minute concentrations, decrease or modify plant length. A similar observation was reported by (Ullah et al. 2022) in the wheat crop using MLE.

Pod plant^{-1} (No.)

The number of pods per plant is an important yield-contributing component of chickpea and also contributes to the seed production of chickpea. As far as the usage of various plant extracts and synthetic growth promoters is concerned, significant results were achieved by their application (Table 3). The maximum (53.33) numbers of pods per plant were observed in potassium sulfate application, followed by amino acid (49.11). The lowest (38.88) number of pods were obtained from control. Our results are confirmed by (Mazid et al. 2015) and (Chuhan et al. 2018) whose use of foliar potassium sulfate gave promising results. This may be due to the readily absorbed foliage of chickpea, which has transformed from vegetative to reproductive stage, and the maximum time availability for pollination, fertilization, and pod formation. There was a non-significant relationship between various growth stages in chickpea. Maximum pod plant^{-1} (No.) 50.86 were recorded at S_3 (pod initiation), followed by S_2 (flowering stage). The lowest (43.93) number of pods were noticed in S_1 (vegetative stage). The interaction between plant growth promoters and chickpea growth stages gave non-significant findings. The maximum number of pods per plant was noted in K_2SO_4 (62.23) after pod initiation, followed by amino acid and iple. Minimal numbers of pods (34.66) were counted at S_1 (vegetative stage) in Iple leaf extract-treated plots.

Grain pod^{-1} (No.)

Grain pod^{-1} (No.) is the yield-contributing factor. The data remained in the range of 1.86 to 2.26. Chickpea grain pod^{-1} (No.) differs significantly due to the foliar application of plant growth promoters (Table 4). Maximum grain pod^{-1} (No.) (2.23) was obtained by using potassium sulfate. The next highest grains, pod^{-1}(1.96) were counted in moringa, followed by amino acid (1.95) and iple (1.94). While least (No.) of grain per pod was counted in control treatment.

Table 3: Effect of plant growth promoters' applications at different growth stages of chickpea on plant height (cm) and pod plant^{-1} (No.)

Plant Growth Regulators	Plant height (cm)				Pod plant^{-1} (No.)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	78.80 ^{NS}	84.43	80.66	**81.33^{NS}**	40.66 ^{NS}	40.66	47.00	**42.77 b**
Iple leaf extract (3%)	78.70	83.30	83.06	**81.68**	34.66	44.00	49.66	**42.77 b**
Amino acid (20%)	77.96	82.23	86.76	**82.32**	44.33	46.33	56.66	**49.11 a**
Potassium sulfate (5%)	81.86	84.10	76.23	**80.73**	47.66	50.00	62.33	**53.33 a**
Control	81.30	83.06	76.16	**80.17**	39.33	38.66	38.66	**38.88 b**
Means	**79.74 ^{NS}**	**83.42**	**80.58**		**43.93**	**50.86**	**50.86**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

The overall improvement in plant growth and development may be attributed to sufficient photosynthesis through increased chlorophyll content of leaves by foliar application of potassium sulfate and other plant growth promoters on the one hand and efficient utilization/immobilization of photosynthesis towards source to sink, which might have been responsible for the increase in the number of grains pod^{-1} (Bairva et al. 2012). They also supported our findings by demonstrating an increase in the number of grains through the application of various growth promoters. Application stages remained non-significant for the number of grains pod^{-1} of chickpea. The highest grains, pod^{-1} (No.) (2.04) were found in pod initiation (S_3), followed by S_2 (2.00) (flowering stage). The lowest grains pod^{-1} (No.) were counted in S_1 (1.97) Vegetative Stage. The interaction among plant growth promoters and their application to different growth stages of chickpea gave insignificant results. The highest number of grains pod^{-1} (2.30) were observed in the treatment combination of potassium sulfate and its application at flowering stage, followed by (2.26) in the in the number of grains pod^{-1} in potassium sulfate used at S_3 (pod initiation stage). However, in control plots, the minimum grains pod^{-1} (1.80) were counted without using any foliar spray.

Sterility (%)

Sterility in the flowers may be due to many reasons, including early temperature rise, drought, and climate change scenarios that influence the sterility of flowers. Plant extracts and synthetic growth promoters significantly influenced the sterility (%) (Table 4). Maximum sterility (%) was shown by the control (31.27%), followed by Moringa leaf extract (30.27%), whereas minimum sterility (22.47%) was calculated in treatments supplied with potassium sulfate. As far as the plant growth promoter's application to various growth stages is concerned, significant results were obtained in the experiment. The highest sterility (%) was calculated in S_1 (30.87%) after the vegetative stage, followed by S_2 (27.86 %), while the lowest sterility was noted in S_3 (25.32 %) after pod initiation. This view is supported by Fatima et al. (2008), who applied plant growth promoters before flowering and significantly reduced the sterility (%) in chickpea. The interaction was not significant statistically. Maximum sterility (%) was achieved by S_1 (35.85 %) after the vegetative stage, followed by moringa (32.41%) at S_1. The next highest sterility (%) (32.32 %) was recorded from the control treatment and then from combination of amino acids and vegetative stage with a sterility of (32.03%). Minimum showed by S_3 (19.80%) after pod initiation. While (Khan et al. 2019) advocated that moringa leaf extracts reduced sterility (%) in wheat.

100 grains weight (g)

The foliar application of plant extracts and synthetic growth promoters resulted in a significant increase in chickpea 100 grain weight (g) (Table 5). The bulky 100-grain weight (14.99 g) was recorded in plots where potassium sulfate application was tested. The maximum 100 grain weight in foliar application of potassium sulfate may be due to its role in the conversion of photosynthates and their transmission from source to sink, whereas the minimum 100 grain weight in control may be due to a lack of proper nutrients through the plant growth promoter's role in grain formation. The foliar applications of other plant growth promoters, such as Moringa leaf extract, Iple leaf extract, and amino acid 100 grain weight, yielded similar statistical results, with readings of 12.88 g, 13.39 g, and 13.63 g, respectively. The control plots recorded the lowest 100-grain weight (11.03). Foliar sprays of potassium sulfate might be quick in action and readily absorbed by the leaves. Findings of our results are in line with (Grotz and Guerinot, 2006) who reported a significant increase in grain weight with foliar application of plant growth promoters. As far as growth stages are concerned, maximum grain weight (13.36 g) was recorded at S_2 (flowering stage), followed by (13.17 g) at S_3 (pod initiation), whereas the minimal grain weight (13.02 g) was recorded in the vegetative stage. Interaction also proved to be insignificant. The maximum 100 grains weight (15.18 g) was recorded in potassium sulfate at S_2 (flowering stage), followed by (14.95 g) and (14.85 g) at S_3 and S_1 in potassium sulfate respectively. The minimum 100-grain weight (10.52 g) was weighed in control.

Grain yield (kg ha^{-1})

Grain yield is the integrated result of all yield-contributing parameters. The favorable effects of spraying plant growth promoters were fully reflected in yield attributes like pods^{-1} (No.), weight of seed plant^{-1}, and seeds pod^{-1}(No.). Significant effect of foliar application of plant extracts and synthetic growth promoters on grain yield in contrast to stages of application and their interaction. Plant growth promoters' application gave significant results on the grain yield of chickpea (Table 5). The highest grain yield of 1835 kg ha^{-1} were obtained from treatments where foliar application of potassium sulfate was utilized, followed by Moringa leaf extract, Iple leaf extract, and amino acids, whose application produced statistically similar grain yields of 1737 kg^{-1}, 1728 kg^{-1} and 1747 kg ha^{-1}, correspondingly. (Khan et al. 2019) obtained the maximum grain yield of wheat by spraying moringa leaf extract under drought and heat stress. The minimum grain yield of 1653 kg^{-1} was recorded from control plots.

Table 4: Effect of plant growth promoters' applications at different growth stages of chickpea on grain pod^{-1} (No.) and sterility (%)

Plant Growth Regulators	Grain pod^{-1}(No.)				Sterility (%)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	1.80^{NS}	1.86	2.13	**1.96b**	32.41	30.14	28.26	**30.27a**
Iple leaf extract (3%)	1.86	1.96	2.00	**1.94b**	35.85	27.67	22.08	**28.53a**
Amino acid (20%)	2.03	1.96	1.86	**1.95b**	32.03	26.56	24.06	**27.55a**
Potassium sulfate (5%)	2.13	2.30	2.26	**2.23a**	24.80	22.62	19.80	**22.47 b**
Control	1.93	1.80	1.93	**1.92b**	29.18	32.31	32.32	**31.27a**
Means	**1.97 ^{NS}**	**2.00**	**2.04**		**30.87a**	**27.86ab**	**25.32b**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

Table 5: Effect of plant growth promoters' applications at different growth stages of chickpea on 100 grain weight (g) and grain yield (kg ha^{-1})

Plant Growth Regulators	100 grain weight (g)				grain yield (kg ha^{-1})			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	12.86 ^{NS}	12.88	12.80	**12.88 b**	1725.1^{NS}	1761.0	1725.3	**1737.1 b**
Iple leaf extract (3%)	13.19	13.70	13.28	**13.39 b**	1727.3	1725.0	1732.3	**1728.2 b**
Amino acid (20%)	13.68	13.54	13.66	**13.63 b**	1720.0	1789.0	1734.7	**1747.9 b**
Potassium sulfate (5%)	14.85	15.18	14.95	**14.99 a**	1876.3	1816.0	1815.0	**1835.8 a**
Control	10.52	11.50	11.07	**11.03 c**	1695.3	1672.7	1591.3	**1653.1 c**
Means	**13.02^{NS}**	**13.36**	**13.17**		**1752.7 ^{NS}**	**1719.7**	**1719.7**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

The highest grain yield through foliar application of potassium sulfate may probably be due to its positive role in grain formation and assimilate conversion to grains, whereas, least grain yield was obtained in controlled plots might be due to a lack of insufficient nutrition in the form of solution sprayed over the crop. These findings are in agreement with those of (Chovatia et al. 2010), (Vagner et al. 2013) and (Sharma and Jain, 2016). Recorded a significant yield increment by using of growth promoting substances. Growth stages showed non-significant results, maximum grain yield 1752.7 kg ha^{-1} was recorded at S_1 (vegetative stage), whereas minimum grain yield (1719.7 kg ha^{-1}) was noted at S_2 flowering stage and S_3 pod initiation The interaction remained non-significant. Maximum grain yield (1876 kg ha^{-1}) was recorded in potassium sulfate at S_1 (vegetative stage), followed by S_2 (1816.0 kg ha^{-1}) and S_3 (1815.0 kg ha^{-1}), while the minimum (1672.7 kg ha^{-1}) was recorded in control plots.

Biological yield (kg ha^{-1})

The foliar application of plant extracts and synthetic growth promoters significantly influenced the biological yield (kg ha^{-1}). While the timing of plant growth promoters (growth stages) and the interaction between two factors result in non-significant variations (Table 6), The plant growth promoter's results revealed that the iple leaf extract and amino acid foliar application remained at par statistically by producing maximum biological yield 5729 kg ha^{-1} and 5647kg ha^{-1}, respectively. Next in order, the plant growth promoters moringa leaf extract, potassium sulfate and control had similar biological yield 5393, 5326, and 52010 kg ha^{-1}, respectively. The control group achieved the minimum biological yield of 5201 kg ha^{-1}.

Table 6: Effect of plant growth promoters' applications at different growth stages of chickpea on biological yield (kg ha^{-1}) and harvest index (%).

Plant Growth Regulators	Biological yield (kg ha^{-1})				Harvest index (%)			
	S_1	S_2	S_3	Means	S_1	S_2	S_3	Means
Moringa leaf extract (3%)	5348.3^{NS}	5409.3	5421.7	**5393.1 b**	32.42^{NS}	32.59	31.86	**32.29 b**
Iple leaf extract (3%)	5834.0	5547.7	5806.3	**5729.3 a**	29.61	31.18	29.84	**30.21 d**
Amino acid (20%)	5672.7	5637.7	5633.3	**5647.9 a**	30.32	31.74	30.79	**30.95cd**
Potassium sulfate (5%)	5411.3	5280.3	5288.3	**5326.7 b**	34.67	34.39	34.35	**34.47 a**
Control	5237.3	5265.3	5100.3	**5201.0 b**	32.37	31.75	31.20	**31.77 bc**
Means	**5500.7^{NS}**	**5428.1**	**5450.0**		**31.88^{NS}**	**32.33**	**31.61**	

S_1: Vegetative Stage, S_2: Flowering Stage, S_3: Pod Initiation
Means having common letters are not significant at P>0.05

The highest values of plant growth promoters (Iple leaf extract and amino acid) may be due to better vegetative growth of crops by increasing water and nutrient uptake, which accelerated photosynthetic rates, thereby increasing the supply of carbohydrates, which resulted in increased cell division and elongation. These are also described by (Sharma and Jain, 2016) and (Bairva et al. 2012). The application stage of the plant growth promoters revealed non-significant variation. The maximum biological yield (5500 kg ha^{-1}) was recorded at S_1 (vegetative stage) and seemed better than S_2 (flowering stage) and S_3 (pod initiation), with biological yield (5428 kg ha^{-1}) and (5450 kg ha^{-1}) respectively. As far as interaction is concerned, it also indicated a non-significant outcome. The maximum biological yield (5834.0 kg ha^{-1}) was recorded in Iple at S_1 (vegetative stage), followed by amino acid (5637 kg ha^{-1}) at S_2 (flowering stage). The minimum biological yield (5100.3 kg ha^{-1}) was weighed in control at S_3 (pod initiation).

Harvest index (%)

Harvest index (%) is the ratio of economic output divided by biological output into 100. Plant extracts and synthetic growth promoters. Growth stages and interactions depicted non-significant results (Table 6). However, various plant growth promoters' applications gave significant results for the harvest index of chickpea. The various plant growth promoters were able to show significant results for the harvest index. The maximum harvest index of 34.47 was calculated for plots where potassium sulfate was applied, followed by Moringa leaf extract 32.29 %. Potassium sulfate foliar application may help in the transmission of photosynthates towards seed and pod formation, thus increasing the grain yield and ultimately the harvest index. Foliar application of potassium sulfate might be readily absorbed in the leaf and help the plant with carbohydrate accumulation and transmission from source to sink at any stage of plant growth, as described by (Sarbandi and Madani, 2014). The minimum harvest index was recorded in treatments of Iple leaf extract 30.21 % and amino acid (30.95 %). The highest harvest index of potassium sulfate applied treatments was due to the maximum grain yield obtained from the same. Stages of the plant growth promoter's application showed significant results; a maximum 32.33 % harvest index was recorded at S_2 (flowering stage). The next best harvest index value of 32.33 % was obtained in S_2 (31.88 %), while the minimum harvest index of 31.61 % was noted in S_3 (pod initiation). The interaction of plant growth promoters and growth stages was not significant statistically. Maximum harvest index % was achieved by potassium sulfate (34.67 %) after flowering stage at S_2. The next best harvest index was obtained from the interaction of S_2 and potassium sulfate (34.39 %) and S_3 with potassium sulfate (34.35 %). The minimum harvest index was depicted by iple leaf extract (29.61 %) after the vegetative stage at S_1.

CONCLUSIONS

The one-year experiment, "Drought Stress Management in Chickpea at various growth stages through the foliar application of plant extracts and growth regulators" concluded that the foliar application of plant growth promoters is helpful in promoting plant growth under drought conditions, based on the results. However, potassium sulfate inorganic plant growth promoters perform better than exogenously sprayed at any growth stage. Conversely, the extracts of moringa and iple outperformed then control group in the parameters under study. In our experiment, the concentration was low at 3%. If we increase the concentration of plant extracts, then natural plant growth promoters may act better than synthetic plant growth promoters. Our results are based on a one-year study; they may be prolonged to a two- or three-year study for a final conclusion.

Supplementary materials

The supplementary material / supporting for this article can be found online and downloaded at:

https://www.isisn.org/article/

Author contributions

Muhammad Jawad Nazir, Ehtesham Ul Haq, and Sami Ullah conducted this research and data collection. Dr. Ghazanfar Ullah and Dr. Iqtidar Hussain contributed to writing the paper. Dr. Shakeel Ahmmad Jatoi and Dr. Abdul Aziz Khakwani helped in table setting and analysis of the data. Muhammad Jawad Nazir and Rashid Abbas set references. All authors approved the final manuscript.

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All of the data is primary.

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Conflict of interest

The authors declared that present study was performed in absence of any conflict of interest.

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REFERENCES

Bahr, A.A. (2007). Effect of plant density and urea foliar application on yield and yield components of chickpea (*Cicer arietinum*). *Research Journal of Agriculture* and *Biological Sciences* (4), 220-223.

Basra, S.M.A., M.N. Iftikhar and I. Afzal, (2011). Potential of moringa (*Moringa oleifera*) leaf extract as priming agent for hybrid maize seeds. *International Journal of Agriculture and Biology*, 13: 1006–1010.

Bairva, M., Meena., S. S., & Mehta, R. S. (2012). Effect of bio-fertilizers and plant growth regulators on growth and yield of fenugreek (*Trigonella foenum graecum* L.). *International Journal of Seed Spices*, *2*(1), 28-33.

Bakhtavar, M.A., I. Afzal, S.M.A. Basra, A.H. Ahmad and M.A. Noor, (2015). Physiological strategies to improve the performance of spring maize (*Zea mays* L.) planted under early and optimum sowing conditions*. PLoS One*, 10: 1–15.

Chovatia RS, Ahlawat TR, Mepa SV, Jat G. (2010). Response of cowpea (*Vigna unguiculata* L.) cv. Guj-4 to the foliar application of plant growth regulating chemicals. *Vegetable Science*, 37(2),196-197.

Chauhan, V., Hirpara, D. S., Bheda, M. K., &Sutaria, G. S. (2018). Response of chickpea (*Cicer arietinum* L.) to plant growth regulators. *Journal of Pharmacognosy and Phytochemistry*, *7*(6), 669-672.

European Bio stimulants Industry Council, 2012. EBIC and Bio stimulants in Brief.

Farooq, M., S.M.A. Basra, H.U. Rehman and B.A. Saleem, (2008). Seed priming enhances the performance of late sown wheat by improving chilling tolerance. *Journal of Agronomy and Crop Science*, 194: 152–1Flowering Stage.

Fatima, Z., Bano, A., Sial, R., &Aslam, M. (2008). Response of chickpea to plant growth regulators on nitrogen fixation and yield. *Pakistan Journal of Botany*, *40*(5).

Grotz, N., & Guerinot, M. L. (2006). Molecular aspects of Cu, Fe and Zn homeostasis in plants. *Biochimicaet Biophysica Acta (BBA)-Molecular Cell Research*, *1763*(7), 595-Flowering Stage 8.

Gravel V, Antoun H, Tweddell RJ. (2007). Growth stimulation and fruit yield improvement of greenhouse tomato plants by inoculation with Pseudomonas putida or Trichoderma atroviride: possible role of indole acetic acid (IAA). *Soil Biology* & *Biochemistry*, 39:1968–1977.

Khalid A, Arshad M, Zahir ZA. (2004). Screening plant growth-promoting rhizobacteria for improving growth and yield of wheat. *Journal of Applied Microbiology,* 96:473–480.

Khan N, Bano A, Rahman MA, Rathinasabapathi B (2018). UPLC-HRMS-based untargeted metabolic profiling reveals changes in chickpea (*Cicer arietinum*) metabolome following long-term drought stress. *Plant Cell & Environment,* https://doi.org/10.1111/pce.13195

Khan, N., Bano, A., & Babar, M. A. (2019). Metabolic and physiological changes induced by plant growth regulators and plant growth promoting rhizobacteria and their impact on drought tolerance in *Cicer arietinum* L. *Plos One,* 14(3).

Maiti R.K. (2001). The Chickpea Crop. In Advances in Chickpea Science, *Science Publishers Inc., Enfield, USA*. pp: 131.

Mazid, M., & Khan, F. (2015). Analysis of Response of Chick-Pea Cultivars to Various Insecticides-A Pot Evaluation. *Conceptual Framework and Innovations in Agro-Ecology and Food Sciences*, *1*(1), 68-72.

Mahmood, I., Razzaq, A., Qayyum, A., & Ali Khan, A. (2017). Mitigating the terminal drought stress in chickpea (*Cicer arientinum* L.) through exogenous application of nutrients. *Journal of Agricultural Research (03681157)*, *55*(2).

Rady, M.A., B.C. Varma and S.M. Howladar, (2013). Common bean (*Phaseolus vulgaris* L.) seedlings overcome NaCl stress as a result of presoaking in Moringa oleifera leaf extract. *Scientia Horticulturae*., 162: 63–70.

Rafique, M., Naveed, M., Mustafa, A., Akhtar, S., Munawa r, M., Kaukab, S., & Salem, M. Z. (2021). The combined effects of gibberellic acid and rhizobium on growth, yield and nutritional status in chickpea (*Cicer arietinum L*.). *Agronomy*, *11*(1), 105.

Steel, R.G.D., Torrie, J.H., & Dicky, D.A. (1997). Principles and procedures of statistics. A biometric approach. 3rd edition. *McGraw Hill Book International Corporation*, New York, 400–428.

Singh B, Usha K. (2003). Salicylic acid induced physiological and biochemical changes in wheat seedlings under water stress. *Plant growth regulators*, 39:137–141.

Sarbandi, H., &Madani, H. (2014). Response yield and yield component of Chickpea to foliar applicationofmicronutrients. *Journal of AppliedScie nce*, *Engineering and Technology*, *4*(1), 18-22.

Semida, W.M. and M.M. Rady, (2014). Pre-soaking in 24-epibrassinolide or salicylic acid improves seed germination, seedling growth and antioxidant capacity in Phaseolus vulgaris L. grown under NaCl stress. *Journal of Horticultural Science and Biotechnology*., 89: 338–344.

Sharma A, Jain N. (2016). A study on effect of gibberellic acid on seed germination of urad bean. *International Journal of Current Microbiology and Applied Sciences*, 5(4):347-350.

Taiz, L. and Zeiger, E. (2003). Auxin – the growth hormone. Plant Physiology, Panima Publishing Corporation, New Delhi. 423-456.

Ullah, S., Hanif, A., Sarwar, N., Irum, A., Malik, A., Irum, A., Hussain, I., Mubeen, A., Parveen, Z., Pasha, M.F.K., & Arshad, N. (2022). Yield Optimization of Drought Stressed Wheat through Exogenous Application of Natural Plant Growth Regulators. *Bioscience Research*, 19(4), 1783-1789.

Vagner, ML., Ciro AR, Joao, D.R. (2013). Gibberellin and cytokinin effects on soybean growth. Scientia Agricola. Flowering Stage (3):10-541.

Vymazal (2007). Removal of nutrients in various types of constructed wetlands. *Science of the total environment*, 380(1-3), 48-65.

Venkateswarlu B, Shanker AK. (2009). Climate change and agriculture: adaptation and mitigation strategies *Indian Journal* of *Agronomy*; 54:226–230

Yasmeen, A., Basra, S.M.A., Wahid, A., Farooq, M., Nouman, W., Rehman, H., & Hussain, N. (2013). Improving drought resistance in wheat (*Triticum aestivum*) by exogenous application of growth enhancers. *International journal of Agriculture and Biology*, 15-6S: 1307–1312.