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Response of chickpea to foliar supply of Hoagland's solution under rain-fed conditions

Resposta do grão-de-bico ao fornecimento foliar da solução de Hoagland em condições de chuva

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Highlights:
Foliar spray of Hoagland's solution applied at different growth stages of chickpea.
Distilled water, 25, 50, and 75% of Hoagland's solution were sprayed.
At 7, 14, and 21 days after crop emergence Hoagland's solution were applied.
Higher strength (75%) of Hoagland's solution enhanced the growth and yield.
The 75% strength of Hoagland's solution sprayed at 21 days after crop emergence produced highest yield.

Abstract

Under rain-fed conditions, foliar application of nutrients is an efficient tool to eliminate the adverse effects of nutrients shortage and helpful to catch the maximum yield of any crop. Field experiments were executed to evaluate the effect of foliar spray of different strengths and application times of Hoagland's solution on growth and yield characteristics of chickpea (*Cicer arietinum* L.) under rain-fed conditions. The treatments consisted of distilled water (control), 25, 50, and 75% strength of Hoagland's solution sprayed at 7, 14, and 21 days after crop emergence (DACE) on two chickpea cultivars C-44 and CM-72. In terms of growth and yield, CM-72 showed superiority over C-44. The 75% strength of Hoagland's solution showed an improvement of 32.9, 37.9, 35.3, 13.5, and 35% in dry weight, plant height, 100-seed weight, seed yield, and biological yield, respectively when sprayed at 21 DACE than distilled water. However, the lower strength (25%) of Hoagland's solution produced similar results to distilled water. It is recommended that under rain-fed conditions chickpea cultivar CM-72 should be cultivated with a foliar supply of 75% strength of Hoagland's solution at 21 DACE to obtain the maximum growth and yield.
Key words: Foliar application. *Cicer arietinum*. Rain-fed. Growth and yield. Nutrients solution. Strength and time.

Resumo

Sob condições de chuva, a aplicação foliar de nutrientes é uma ferramenta eficiente para eliminar os efeitos adversos da falta de nutrientes e útil para obter o rendimento máximo de qualquer cultura. Experimentos de campo foram executados para avaliar o efeito do spray foliar de diferentes forças e

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tempos de aplicação da solução de de Hoagland sobre as características de crescimento e rendimento do grão de bico (*Cicer arietinum* L.) e m condições de chuva. Os tratamentos foram constituídos por água destilada (controle), 25, 50 e 75% da solução de Hoagland pulverizada aos 7, 14 e 21 dias após a emergência da colheita (DACE) em duas cultivares de grão de bico (C-44 e CM-72). Em termos de crescimento e rendimento, o CM-72 mostrou superioridade em relação ao C-44. A aplicação de 75% da solução de de Hoagland mostrou uma melhoria de 32,9, 37,9, 35,3, 13,5 e 35% em peso seco, altura da planta, peso de 100 sementes, rendimento de sementes e rendimento biológico, respectivamente, quando pulverizados a 21 DACE do que a água destilada. No entanto, a menor dose(25%) da solução de de Hoagland produziu resultados semelhantes aos da água destilada. Recomenda-se que, em condições de chuva, a cultivar CM-72 seja cultivada com suprimento foliar de 75% da solução de de Hoagland em 21 DACE para obter o máximo crescimento e rendimento.

Palavras-chave: Aplicação foliar. *Cicer arietinum*. Sequeiro. Crescimento e produtividade. Solução de nutrientes. Força e tempo.

Introduction

Chickpea (*Cicer arietinum* L.) is an important pulse crop (Turner, 2004) of subcontinent and Middle East. It is valued crop and provides nutritious food for an escalating world population (Muehlbauer & Sarker, 2017). Such a high-value crop it needs to increase its yield. Perhaps, under rain-fed conditions chickpea faces several challenges including sub-optimal and erratic rainfall, depleted soils, poor nutrients status of soil, and resource-poor farmers (Singh, Ramakrishna, Sharma, & Venkateswarlu, 1999). To achieve this level of consistent higher yield under such circumstances, adequate management strategies are need to be evolved.

Foliar application of nutrients may be a substitute method to attain maximum crop yield under rain-fed conditions (Ali et al., 2002**)**. Both micro and macro-nutrients play a significant role in the plant structure, plant cell osmoregulation, and metabolism (Taiz & Zeiger, 2009). Deficiency of nutrients, toxicity of ions, and osmotic stress are the main factors that exert deleterious effects on plant growth and yield (Nublat, Desplans, Casse, & Berthomieu, 2001). To increase the yield it is necessary to maintain the nutrients at optimum level (Hu, Ye, Shi, Duan, & Xu, 2010). Although, soil fertilization is one of the most frequent ways to provide nutrients to plants from which plants absorbed essential nutrients through their roots but it was less economical for the plants which have low demand for nutrients (Fageria, 2016). Some times nutrients present in the soil medium are not enough to meet the nutritional demand of the plant as well as it is difficult to apply in rain-fed areas (Hussain, Rehman, Khan, Roohullah, & Ahmed, 2006; Jahiruddin, Ali, Hossain, Ahmed, & Hoque, 1995).

There are many approaches to nourish the crop plant whereas, foliar spray of nutrients is observed as the most efficient technique in relation to nutrients uptake (Sahai, 2004). Foliar application of nutrients is the alternate method to fulfill the nutritional demand of crop plants (Arif, Chohan, Ali, Gul, & Khan, 2006). According to previous reports Mo, Zn, and B application significantly improved the yield of chickpea (Johansen et al., 2007; Salih et al., 2013). Foliar nutrients applications resulted in the reduction of many crop diseases and nutritional disorders in minimum time (Kuepper, 2003). Fernández and Eichert (2009) reported that application of nutrients by foliar spray is the ancient method that is most effective to minimize the nutritional deficiency in crop plants. As compared to soil application, foliar application results in quick uptake of nutrients (Kannan, 2010). Foliar-applied nutrients may also be used to resolve many physiological disorders which may be due to the deficiency of nutrients and also helps the plant to cope under various biotic and abiotic stresses (Kerin, & Berova, 2003; Fageria, Barbosa, Moreira, & Guimaraes, 2009). Different nutrients mixtures have been discovered for plant growth and development among which Hoagland's solution has been used extensively for integrated crop production (Li & Cheng, 2015; Schwabe et al., 2013; Maneetong et al., 2013).

For improvement in chickpea growth and yield under rain-fed conditions, appropriate nutrition is essential. Therefore, foliar application of Hoagland's solution is one of the most efficient ways to cope up the nutritional demand of crop plants as it is the combination of both nutrients. Thus, the present study was performed to investigate the chickpea response to the foliar supply of Hoagland's solution under rain-fed conditions.

Materials and Methods

Site description

To investigate the response of chickpea to the foliar supply of Hoagland's solution the field experiments were conducted at Agronomic Research Area (Latitude 31.41 °N, Longitude 74.17 E and Altitude 194.4 m), College of Agriculture, University of Sargodha, Sargodha, Pakistan during 2016-2017 and 2017-2018. Before the sowing of the crop, soil analysis of the experimental site was performed. The soil was sandy loam with a pH of 7.9, soil organic matter 0.56%, 0.43% N, 10 mg kg^{-1} extractable P, and 103 mg kg^{-1} available K. Throughout the whole experimental period, the day-to-day maximum or minimum temperature and rainfall scatterings are shown in figure 1. The total rainfall throughout the chickpea growth period was 312.6 mm.

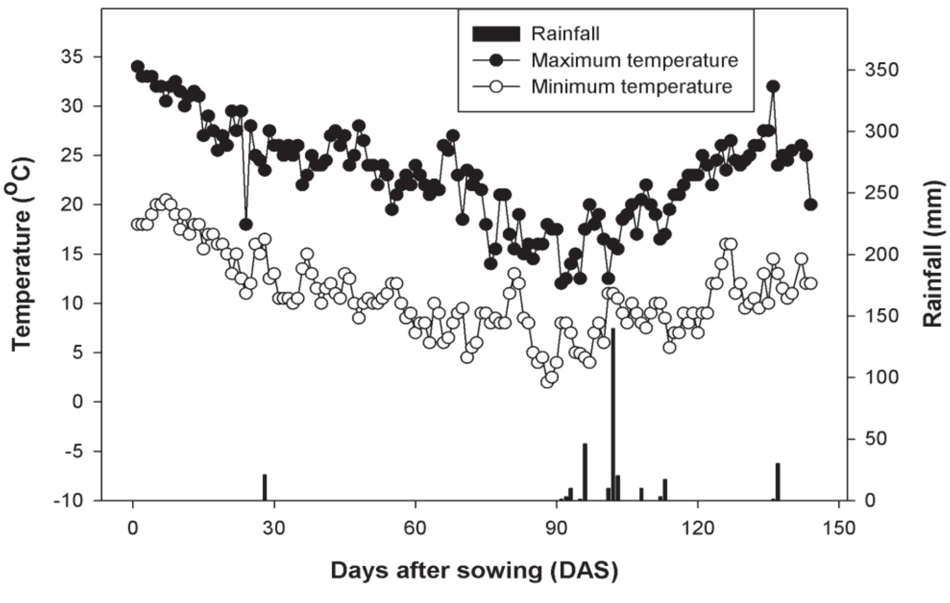

Figure 1. Two years average day-to-day maximum or minimum temperatures and rainfall throughout the chickpea growing seasons of the experimental site at Sargodha, Punjab Province, Pakistan.

Experimental design and treatments

The experiments were conducted in a randomized complete block design (RCBD) with a factorial arrangement and each treatment was replicated four times. Treatments consist of distilled water, 25, 50, and 75% strength of Hoagland's solution each applied at 7, 14, and 21 days after the emergence of chickpea. Hoagland's solution was developed according to the procedure of Hoagland and Arnon (Hoagland & Arnon, 1950; Epstein, 1972). The nutrient concentrations of Hoagland's solution were reduced to one-fourth, one-half, and three-fourth to prepare reduced strengths (25, 50 and 75%) of Hoagland's solution.

Table 1
Composition of modified Hoagland's solution (Epstein, 1972)

Compound	Stock solution concentration		mL in a liter of solution
	mM	g L^{-1}	
Macronutrients			
KNO_3	1,000	101.10	6.0
$NH_4H_2PO_4$	1,000	115.08	2.0
$Ca(NO_3)_2.4H_2O$	1,000	236.16	4.0
$MgSO_4.7H_2O$	1,000	246.49	1.0
Micronutrients			
KCl	25.0	1.864	2.0
H_3BO_3	12.5	0.773	2.0
$MnSO_4.H_2O$	1.0	0.169	2.0
$ZnSO_4.7H_2O$	1.0	0.288	2.0
$CuSO_4.5\ H_2O$	0.25	0.062	2.0
H_2MoO_4 (85% MoO_3)	0.25	0.040	2.0
NaFeDTPA (10% Fe)	64.0	30.00	1.0

Macronutrients were added separately from the stock solution to prevent precipitation. A combined stock solution was prepared containing all micronutrients except iron.

Experiment managements

The seedbed was prepared by cultivating the field two times with tractor-mounted cultivar each followed by planking. Two varieties of chickpea viz: C-44 and CM-72 were sown on 15th October 2016 and 17th October 2017 with a single row hand drill at a seed rate of 40 kg ha^{-1}. The plot size was 3 m × 1.8 m. At two to four-leaf stages, the crop was thinned to maintain the plant to plant distance of 10 cm. Pre-emergence herbicide, dual gold was sprayed @ 2.5 L ha^{-1} to keep the field free from weeds. Hoagland's solution was sprayed with a backpack sprayer equipped with a flat-fan nozzle at chosen growth stages (Tee jet 8002E Nozzle, Spraying Systems Company, Wheaton, IL) calibrated to deliver 250 L ha^{-1} at a walking speed of 3.2 km ha^{-1}. All other agronomic practices such as hoeing and plant protection measure were kept normal and uniform for each plot. The crop was harvested when about more than 90% of pods had reached to maturity.

Data collection

During both growing season after seven days of the last spray of Hoagland's solution application dry weight of chickpea plants was noted. Five plants were selected at random from each treatment. Each plant weighed on an electric balance and then plants dried in an oven at 72ºC for 48 hours. Data of plant height, number of pods per plant, pod length, number of seed per pod, and 100-seeds weight were recorded at maturity by harvesting ten plants in each plot by using standard procedure. To get seed yield, the chickpea plants were harvested at maturity from each plot, dried in the sun, and threshed manually. The biological yield was recorded by collecting the total plant biomass from every plot, dried in the sun for some days, and then changed to t ha^{-1}. The harvest index (%) of chickpea was described as a ratio of grain yield to biological yield. It was determined by using the following formula.

$$\text{HI }(\%) = \frac{\text{Grain Yield}}{\text{Biological yield}} \times 100$$

Statistical analysis

Data of both years were pooled because the year effect was non-significant. Data collected on growth and yield parameters were analyzed statistically by using Statistix 8.1 software analysis of variance techniques and the significance of treatments was tested using Tukey's (HSD) test at a 5% probability level (Steel, Torrie, & Dicky, 1997). Pre-planned orthogonal contrasts with a single degree of freedom were used to compare Hoagland's solution strengths and application time of each strength. The graphical representation of the data was performed by using Sigma Plot 11.0. Average of both year's data was presented for each parameter.

Results and Discussion

Chickpea dry weight was recorded seven days after the last spray of Hoagland's solution. Data in table 2 indicated that the dry weight of chickpea significantly affected by various application times and strengths of Hoagland's solution. The highest dry weight per plant (34.7 g) was recorded with 75% strength of Hoagland's solution applied at 21 days after crop emergence (DACE). The chickpea cultivar CM-72 produced more dry weight than that of C-44. Foliar application of distilled water gave the lowest dry weight of chickpea (Table 2).

At earlier growth stages (7 or 14 DACE), chickpea plants required less amount of nutrients that can be fulfilled from the soil. However, an increase in the size of chickpea plants aggravated their nutrient needs, and the application of Hoagland's at 21 DACE fulfilled this increased nutrients requirements and hence, enhanced the growth, yield, and its components. So, the increase in plant dry weight might be due to taller plants. These results are in accordance with the findings of Waheed et al. (2019) and Sarwar, Ashraf and Javaid (2017), who reported that the dry weight of mash bean and mung bean improved significantly with 75% strength of Hoagland's solution applied at 21 DACE. Similarly, Krishnaveni, Anandha, Palchamy and Mahendran (2004) reported that foliar spray of nutrients at a suitable growth stage increased the growth of green gram.

Chickpea plant height of both cultivars was significantly influenced by the exogenous application of Hoagland's solution applied at different growth stages (Table 2). The plant height of CM-72 was more than C-44. Data indicated that 75% strength of Hoagland's solution applied at 21 DACE produced a taller plant which was similar to that with the same strength of Hoagland's solution when sprayed at 7 or 14 DACE. However, the lowest plant height of chickpea was observed in plots where distilled water was applied. The difference in plant height of chickpea varieties might be due to genetic variation among the varieties and variable response to the foliar spray of Hoagland's solution. Scientists reported that plant height is a genetically controlled parameter and may vary in response to several rates of added fertilizers (Rahim, Mia, Mahmud, & Afrin 2008; Law-Ogbomo & Egharevba, 2009; Bozorgi, Azarpour, & Moradi, 2011). According to Valenciano, Boto, & Marcelo (2010), chickpea varieties and nutrient applications showed significant differences in plant height. The more height of the chickpea plant due to the foliar spray of Hoagland's solution might have been due to the adequate and balanced nutrition that enhanced growth- and growth-related parameters.

Table 2
Dry weight, plant height and pod length of two chickpea cultivars as influenced by different application time and strengths of Hoagland's solution

Treatment	Dry weight (g) per plant			Plant height (cm)			Pod length (cm)		
	C-44	CM-72	Mean	C-44	CM-72	Mean	C-44	CM-72	Mean
DW at 7 DACE	18.8^{NS}	31.2	25 d	38.3^{NS}	66.9	52.6 d	2.31^{NS}	2.56	2.43 cd
HS_{25} at 7 DACE	24.7	36.7	30.7 abcd	42.3	66.0	54.2 cd	2.67	3.12	2.90 abcd
HS_{50} at 7 DACE	28.1	36.7	32.4 abc	53.9	75.3	64.3 ab	2.85	3.02	2.93 abcd
HS_{75} at 7 DACE	30.1	37.5	33.8 ab	54.7	78.1	66.6 a	3.20	3.55	3.37 ab
DW at 14 DACE	21.8	33.3	27.5 bcd	37.6	63.1	50.4 d	2.30	2.70	2.50 cd
HS_{25} at 14 DACE	25.8	33.8	29.8 abcd	43.9	67.3	55.6 cd	2.88	3.25	3.06 abc
H_{50} at 14 DACE	29.2	36.7	33 ab	53.4	75.8	64.6 ab	3.17	3.37	3.27 ab
HS_{75} at 14 DACE	29.9	34.3	32.1 abc	56.2	78.0	67.6 a	3.50	3.26	3.38 ab
DW at 21 DACE	23.5	29.5	26.1 cd	35.9	63.3	49.6 d	2.05	2.71	2.38 d
HS_{25} at 21 DACE	22.8	32.1	27.8 bcd	46.4	70.9	58.7 bc	2.75	2.67	2.71 bcd
HS_{50} at 21 DACE	28.9	35.6	32.2 abc	53.2	76.7	64.9 a	3.17	3.30	3.23 ab
HS_{75} at 21 DACE	32.6	36.8	34.7 a	58.8	77.9	68.4 a	3.45	3.52	3.48 a
HSD (0.05)	1.61		6.69	1.45		6.04	0.16		0.67
Mean of cultivars	**26.3 b**	**34.5 a**		**48.0 b**	**71.6 a**		**2.86 b**	**3.08 a**	

Mean sharing the same letter within the column did not differ with each other at 5% level of probability
DW = Distilled water, **HS_{25}** = 25% strength of Hoagland's solution, **HS_{50}** = 50% strength of Hoagland's solution, **HS_{75}** = 75% strength of Hoagland's solution, **DACE** = days after crop emergence, **NS** = non-significant.

In case of pod length, CM-72 produced larger pods than of that C-44 (Table 2). Foliar application of Hoagland's solution applied at 7, 14, and 21 DACE shown that the highest pod length (3.48 cm) was recorded with 75% strength of Hoagland's solution applied at 21 DACE. Table 2 exhibited that 50% strength of Hoagland's solution applied at 21 DACE produced almost similar pod length to that with 75% strength of Hoagland's solution applied at 7 DACE. The enhancement in pod length of chickpea with the foliar spray of 75% strength of Hoagland's solution applied at 21 DACE might be due to more production of photosynthates due to absorption and translocation of applied nutrients. Pod length is the key component that determines the productive ability of chickpea. Liu, Andersen and Jensen (2003) reported that imbalance nutrition caused yield losses due to an intensification of floral and pod abortion. Application of Hoagland's solution containing N and other plant growth regulators significantly enhanced the chickpea N fixation, plant height, pods per plant, and pod length (Fatima, Bano, Sial, & Aslam, 2008).

The number of pods per plant deferred significantly between the chickpea cultivars. Cultivar CM-72 produces more number of pods per plant than that of C-44. Table 3 showed that 75% strength of Hoagland's solution sprayed at 21 DAEC resulted in the maximum number of pods per plant as compared to distilled water spray. However, no difference was observed in the number of pods per plant with 75% strength of Hoagland's solution when sprayed at 7 or 14 DACE. Interaction of cultivars × Hoagland's strengths was significant and showed that the highest number of pods per plant was measured in CM-72 with 75% strength of Hoagland's solution sprayed at 21 DACE (Table 3). Different times and strengths of solution significantly improved the number of seeds per pod in both cultivars. The increase in the number of seeds per pod due to foliar application of Hoagland's solution was more in C-44 than CM-72 (Table 3). The 75% strength of Hoagland's solution recorded the maximum (1.8) number of seed per pod which was followed by the same strength of Hoagland's solution applied 7 or 14 DACE (Table 3). The increase in the number of pods per plant and number of seeds per pod with 75% strength of Hoagland's solution sprayed at 21 DACE may be due to optimum strength and time of application that mitigated the deleterious effects of abiotic stresses and improved the number of pods per plant and seeds per pod. Application of nutrients solutions such as molybdenum, zinc, and boron resulted in an increased number of pods per plant, grains per pod, 100-seed weight, and seed yield of chickpea under pot culture (Valenciano et al., 2010).

These findings are further supported by Jha, Sharma and Amarawat (2015) who revealed that foliar spray of iron and zinc significantly enhanced the number of pods per plant in black gram. Okweche, & Avav (2013) stated that various nutrients application significantly augmented the number of pods per plant in mung bean. Rahman et al. (2014) also reported that foliar spray of micro-nutrients (B + Mo + Zn) increased the number of seeds per pod in common bean. Chickpea genotypes and nutrient applications showed significant differences in the number of seeds per pod (Ghassemi-Golezani & Taifeh-Noori, 2010). These findings are in agreement with Shahid et al. (2012) who revealed that chickpea varieties showed significant variability for number of pods per plant, number of seeds per pod, and seed yield under salinity stress by the application of Hoagland's solution.

Table 3
Number of pods per plant, number of seeds per pod and 100-seed weight of two chickpea cultivars as influenced by different application time and strengths of Hoagland's solution

Treatment	Number of pod per plant			Number of seeds per pod			100-seed weight		
	C-44	**CM-72**	**Mean**	**C-44**	**CM-72**	**Mean**	**C-44**	**CM-72**	**Mean**
DW at 7 DACE	73.4 cde	81.8 abcde	77.6 b	1.52^{NS}	1.57	1.54 d	16.2^{NS}	16.5	16.3 d
HS_{25} at 7 DACE	83.9 abcde	85.4 abcd	84.6 ab	1.68	1.63	1.65 abcd	17.5	18.5	18 cd
HS_{50} at 7 DACE	87.3 abcde	91.1 abc	89.2 a	1.77	1.8	1.78 abc	19.2	22.7	21 abc
HS_{75} at 7 DACE	90.5 abcd	93.3 ab	91.9 a	1.93	1.67	1.80 ab	21.2	21.7	21.5 ab
DW at 14 DACE	78.1 bcde	84.7 abcde	81.4 ab	1.56	1.56	1.56 d	16.5	17.2	16.8 d
HS_{25} at 14 DACE	73.8 de	90.7 abc	82.2 ab	1.65	1.55	1.60 bcd	17.7	20.2	19 bcd
H_{50} at 14 DACE	83.4 abcde	96.4 ab	89.9 a	1.80	1.70	1.75 abcd	20.2	20.5	20.3 abc
HS_{75} at 14 DACE	90.5 abcd	94.5 ab	92.5 a	1.85	1.75	1.80 ab	22	21.2	21.6 ab
DW at 21 DACE	77.7 bcde	73.6 de	75.5 b	1.69	1.52	1.61 bcd	17.5	19.2	18.3 bcd
HS_{25} at 21 DACE	86.1 abcde	84.1 abcde	85.1 ab	1.57	1.56	1.57 cd	18.7	18.7	18.7 bcd
HS_{50} at 21 DACE	91.5 abc	92 abc	91.7 a	1.85	1.74	1.80 ab	19.7	21.5	20.6 abc
HS_{75} at 21 DACE	87.9 abcd	97.8 a	92.8 a	1.95	1.72	1.83 a	23.5	22.5	23 a
HSD (0.05)	2.79		11.59	0.05		0.22	0.79		3.50
Mean of cultivars	**83.2 b**	**88.8 a**		**1.73 a**	**1.65 b**		**19.1 b**	**20.0 a**	

Mean sharing the same letter within the column did not differ with each other at 5% level of probability
DW = Distilled water, **HS_{25}** = 25% strength of Hoagland's solution, **HS_{50}** = 50% strength of Hoagland's solution, **HS_{75}** = 75% strength of Hoagland's solution, **DACE** = days after crop emergence, **NS** = non-significant.

All tested strengths of Hoagland's solution imparted a beneficial effect on the 100-seeds weight of chickpea cultivars. The CM-72 recorded a higher (20 g) 100-seeds weight over C-44 (19.1 g) (Table 3). Of all the treatments, 75% strength of Hoagland's solution produced a maximum (23 g) 100-seeds weight of chickpea. Results also revealed that lower strength (25% strength of Hoagland's solution) and distilled water sprayed at 7 DACE did not improve the 100-seeds weight. In our results, foliar spray of 75% strength of Hoagland's solution applied at 21 DACE enhances the 100-seed weight that might have been due to balance nutrient status within the plants which helped to produce more photosynthates and plants were capable to shift these photosynthates into the reproductive parts. According to Arif et al. (2006), foliar spray of nutrients significantly improved the grain weight. These results are in agreement with Fatima et al. (2008) who stated that foliar application of Hoagland's solution containing N and other plant growth regulators significantly enhanced the chickpea N fixation, plant height, pods per plant, pod length, 100-seeds weight, and seed yield.

There was a non-significant effect of various strengths of Hoagland's solution on the biological yield of chickpea cultivars. However, the foliar application of Hoagland's solution applied at different growth stages to chickpea showed substantial response (Table 4). Among the different strengths and growth stages, 75% strength of Hoagland's solution applied at 21 DACE recorded maximum biological yield (7.58 t ha^{-1}) (Table 4). Data also suggested that the lowest (25%) strength of Hoagland's solution applied at 7, 14 and 21 DACE produced similar results. The minimum value of biological yield (5.76 t ha^{-1}) was observed with distilled water spray. The increase in biological yield might be due to balance nutrients application which enhanced the growth of chickpea. These results are in accordance with Chakmak (2010) who stated that the yield of chickpea is severely affected by nutrient deficiency. The results are also supported by Arif et al. (2006) who reported that biological yield improved considerably by foliar spray of nutrient solution consisting of N, P, and K at the rate of 100 g L^{-1} and all micronutrients applied at the rate of 0.8 g L^{-1}. Khan, Fuller and Baluch (2008) also described that at the lateral growth stage, biological yield of wheat enhanced due to the foliar application of micro-nutrients.

All strengths of Hoagland's solution impart a significant impact on chickpea yield. Cultivar CM-72 recorded higher seed yield as compared to C-44. Exogenous application of 75% strength of Hoagland's solution applied at 21 DACE recoded maximum seed yield which was followed by the same strength of Hoagland's solution applied at 14 or 7 DACE (Table 4). In CM-72 highest seed yield (3.5 t ha^{-1}) was measured with 75% strength of Hoagland's solution applied at 21 DACE. Results of the study suggested that 75% strength of solution at 21 DACE was more effective to obtain a higher seed yield of chickpea. An increase in seed yield of chickpea with the foliar spray of Hoagland's solution may be due to more chlorophyll formation and photosynthesis. Arif et al. (2006) stated that foliar spray of nutrients significantly augmented the seed yield. Zain et al. (2015) also reported that the seed yield of wheat improved from 24 to 38% in wheat by foliar spray of micro-nutrients ($FeSO_4 + ZnSO_4 + MnSO_4$). Similarly, Waheed et al. (2019) concluded that 75% strength of Hoagland's solution applied 21 days after emergence significantly improved the grain yield of mash bean. The deficiency of different nutrients resulted in a reduction of plant growth and yield. The deficiency of boron resulted in 10% yield losses (Ahlawat, Gangaiah, & Ashraf 2007). The results of Sadeghi and Noorhosseini (2014) showed that nutrients application efficiently prohibited the occurrence of chlorosis and significantly augmented the seed yield of lentil.

Foliar spray of different strengths of Hoagland's solution affected the Harvest index (%) of tested chickpea cultivars. The harvest index of CM-72 (48.48%) was higher over C-44 (45.86%). While the effect of different strengths of Hoagland's solution under different growth stages was non-significant (Table 4). Our study is supported by the findings of Hussain et al. (2006) who described that harvest index did not decrease significantly by nutrients application. These results are contrary with the results of Khan et al. (2008) who stated that harvest index augmented significantly by foliar spray of micro-nutrients applied at different growth stages.

Orthogonal contrasts of various application times and strengths of Hoagland's solution for growth, yield, and its components of chickpea cultivars presented in table 5. The selected contrasts for comparison were HS_{25} vs. HS_{50}, HS_{25} vs. HS_{75} and HS_{50} vs. HS_{75} strength of Hoagland's solution whereas contrasts for application time of Hoagland's solution were 7 DACE vs. 14 DACE, 7 DACE vs. 21 DACE, and 14 DACE vs. 21 DAEC (HS = Hoagland's solution: $_{25}$, $_{50}$ and $_{75}$ are the strength of Hoagland's solution percentage). The contrasts of HS_{25} vs. HS_{50}, HS_{25} vs. HS_{75} and HS_{50} vs. HS_{75} were significant for plant height, pod length, 100-seeds weight, and seed yield (Table 5). Results of these contrasts showed that growth and yield of chickpea improved with an increase in the strength of Hoagland's solution. However, the contrast of HS_{50} vs. HS_{75} strength of Hoagland's solution was non-significant for dry weight, number of pods per plant, number of seeds per pod, and harvest index. The HS_{75} strength of Hoagland's solution indicated higher values of these traits than those obtained for HS_{25}or HS_{50} (Table 5).

Contrasts comparisons for application time of Hoagland's solution were planned in table 5. Data showed that application time of Hoagland's solution significantly affected the growth and yield traits of chickpea. The contrast of 7 DACE vs. 21 DACE was significant for plant height, number of pod per plant, 100-seeds weight, biological and seed yield. Whereas, the contrasts 7 DACE vs. 14 DACE and 14 DACE vs. 21 DACE was significant for biological yield. These results suggested that foliar spray of Hoagland's solution applied at 21 DACE was more effective than 7 or 14 DACE in terms of growth and yield. Contrasts of 7 DACE vs. 14 DACE and 14 DACE vs. 21 DACE was non-significant for all studied traits except biological yield (Table 5).

Table 4
Biological yield, seed yield and harvest index of two chickpea cultivars as influenced by different application time and strengths of Hoagland's solution

Treatment	Biological yield (t ha^{-1})			Seed yield (t ha^{-1})			Harvest index (%)		
	C-44	CM-72	Mean	C-44	CM-72	Mean	C-44	CM-72	Mean
DW at 7 DACE	5.20^{NS}	6.33	5.76 d	2.85^{NS}	3.07	2.96 f	41.6^{NS}	46.1	43.9^{NS}
HS_{25} at 7 DACE	6.33	7.08	6.70 abcd	2.94	3.19	3.07 de	48.5	46.0	47.2
HS_{50} at 7 DACE	7.09	7.27	7.18 abc	3.10	3.33	3.21 b	44.0	46.3	45.1
HS_{75} at 7 DACE	7.48	7.32	7.40 ab	3.24	3.50	3.37 a	50.0	46.9	48.4
DW at 14 DACE	5.85	6.62	6.24 bcd	2.87	3.10	2.99 ef	42.3	47.0	44.7
HS_{25} at 14 DACE	6.67	6.74	6.70 abcd	2.96	3.23	3.10 cd	44.6	48.5	46.6
H_{50} at 14 DACE	7.53	6.95	7.24 ab	3.10	3.35	3.23 b	43.9	51.6	47.8
HS_{75} at 14 DACE	7.36	7.51	7.43 ab	3.29	3.51	3.40 a	48.2	52.6	50.4
DW at 21 DACE	5.99	5.82	5.91 cd	2.86	3.05	2.96 f	40.8	48.5	44.6
HS_{25} at 21 DACE	6.23	6.45	6.34 abcd	2.97	3.23	3.10 cd	48.2	51.5	49.9
HS_{50} at 21 DACE	7.18	7.13	7.16 abc	3.06	3.33	3.19 bc	42.7	46.8	44.8
HS_{75} at 21 DACE	7.90	7.26	7.58 a	3.21	3.52	3.36 a	55.0	49.5	52.2
HSD (0.05)	0.31		1.31	0.02		0.09	2.28		9.48
Mean of cultivars	**6.73 a**	**6.87 a**		**3.04 b**	**3.29 a**		**45.8 b**	**48.4 a**	

Mean sharing the same letter within the column did not differ with each other at 5% level of probability
DW = Distilled water, $\mathbf{HS_{25}}$ = 25% strength of Hoagland's solution, $\mathbf{HS_{50}}$ = 50% strength of Hoagland's solution, $\mathbf{HS_{75}}$ = 75% strength of Hoagland's solution, **DACE** = days after crop emergence, **NS** = non-significant.

Table 5
Orthogonal contrasts comparing the impact of different strength and application time of Hoagland's solution on dry weight, plant height, number of seeds per pod, pod length, 100-seed weight, biological yield, seed yield and harvest index of chickpea

Contrast Comparison	Dry weight (g) per plant	Plant height (cm)	Pod length (cm)	Number of pods per plant	Number of seeds per pod	100-seed weight	Biological yield (t ha^{-1})	Seed yield (t ha^{-1})	Harvest index (%)
HS_{25} vs. HS_{50}	[a]29.0 vs. 32.5**	56.1 vs. 64.6**	2.8 vs. 3.1*	83.9 vs. 90.2**	1.60 vs. 1.77**	18.5 vs. 20.6**	6.58 vs. 7.19**	3.09 vs. 3.21**	47.9 vs. 45.9*
HS_{25} vs. HS_{75}	29.0 vs. 33.5**	56.1 vs. 67.3**	2.8 vs. 3.4**	83.9 vs. 92.4**	1.60 vs. 1.81**	18.5 vs. 22.0**	6.58 vs. 7.47**	3.09 vs. 3.37**	47.9 vs. 50.4^{NS}
HS_{50} vs. HS_{75}	32.5 vs. 33.5^{NS}	64.6 vs. 67.3**	3.1 vs. 3.4*	90.2 vs. 92.4.1^{NS}	1.77 vs. 1.81^{NS}	20.6 vs. 22.0*	7.19 vs. 7.47^{NS}	3.21 vs. 3.37**	45.9 vs. 50.4^{NS}
7 DACE vs. 14 DACE	30.4 vs. 30.6^{NS}	58.9 vs. 59.5^{NS}	2.9 vs. 3.0^{NS}	85.8 vs. 86.5^{NS}	1.69 vs. 1.67^{NS}	19.2 vs. 19.4^{NS}	6.61 vs. 6.90*	3.15 vs. 3.18^{NS}	46.2 vs. 47.3^{NS}
7 DACE vs. 21 DACE	30.4 vs. 30.2^{NS}	58.9 vs. 60.4*	2.9 vs. 2.95^{NS}	85.8 vs. 86.2*	1.69 vs. 1.70^{NS}	19.2 vs. 20. 1*	6.61 vs. 6.74*	3.15 vs. 3.22*	46.2 vs. 47.9^{NS}
14 DACE vs. 21 DACE	30.6 vs. 30.2^{NS}	59.5 vs. 60.4^{NS}	3.0 vs. 2.95^{NS}	86.5 vs. 86.2^{NS}	1.67 vs. 1.70^{NS}	19.4 vs. 20. 1^{NS}	6.90 vs. 6.74*	3.18 vs. 3.22^{NS}	47.3 vs. 47.9^{NS}

[a] Value in the table are the average of response. Abbreviations: HS_{25} = 25% strength of Hoagland's solution, HS_{50} = 50% strength of Hoagland's solution, HS_{75} = 75% strength of Hoagland's solution, DACE = days after crop emergence.
*Comparisons are significant at $p \leq 0.05$ level of probability.
** Comparisons are significant at $p \leq 0.01$ level of probability.
^{NS} Comparisons are non-significant.

Conclusion

Foliar spray of different strengths of Hoagland's solution applied at different growth stages significantly affected the growth and yield of chickpea. The chickpea variety CM-72 showed superiority over C-44 in terms of growth and yield. However, 75% strength of Hoagland's solution found to be the best in producing maximum 100-seeds weight, seed yield, and biological yield when sprayed at 21 days after chickpea emergence. It is suggested that to achieve maximum chickpea growth and yield, cultivar CM-72 should be planted and sprayed with 75% strength of Hoagland's solution at 21 DACE under rain-fed conditions.

References

Ahlawat, I. P. S., Gangaiah, B., & Ashraf, Z. M. (2007). Nutrient management in chickpea. In S. S. Yadav, R. Redden, W. Chen, & B. Sharma (Eds.), *Chickpea breeding and management* (pp. 213-232). CAB International, Wallingford, Oxon, United Kingdom.

Ali, Y., Krishnamurthy, L., Saxena, N. P., Rupela, O. P., Kumar, J., & Johansen, C. (2002). Scope for genetic manipulation of mineral acquisition in chickpea. In J. J. Adu-Gyamfi (Ed.), *Food security in nutrient-stressed environments: exploiting plants' genetic capabilities* (pp. 165-176). Dordrecht: Springer. doi: 10.1007/978-94-017-1570-6_18

Arif, M., Chohan, M. A., Ali, S., Gul, R., & Khan, S. (2006). Response of wheat to foliar application of nutrients. *American Journal of Agriculture and Biological Sciences, 1*(4), 30-34.

Bozorgi, H. R., Azarpour, E., & Moradi, M. (2011). The effects of bio mineral nitrogen fertilization and foliar zinc spraying on yield and yield components of faba bean. *World Applied Sciences Journal, 13*(6), 1409-1414.

Chakmak, I. (2010). Enrichment of fertilizers with zinc: an excellent investment for humanity and crop production in India. *Journal of Trace Element and Medical Biology, 23*(4), 281-289. doi: 10.1016/j.jtemb.2009.05.002

Epstein, E. (1972). *Mineral nutrition of plants: principles and perspectives.* New York: Pimprenta.

Fageria, N. K. (2016). *The use of nutrients in crop plants*. New York: Taylor Francis.

Fageria, N. K., Barbosa, M. P. F., Moreira, A., & Guimaraes, C. M. (2009). Foliar fertilization of crop plants. *Journal of Plant Nutrition*, *32*(6), 1044-1064. doi: 10.1080/01904160902872826

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), 2005-2013. Recovered from https://agris.fao.org/agris-search/search.do?recordID=PK2011000399

Fernández, V., & Eichert, T. (2009). Uptake of hydrophilic solutes through plant leaves: current state of knowledge and perspectives of foliar fertilization. *Critical Review of Plant Sciences, 182*(1-2), 36-68. doi: 10.1080/07352680902743069

Ghassemi-Golezani, K., & Taifeh-Noori, M. (2010). Soybean performance under salinity stress. *Biochemistry, Chemistry and Physiology, 23*(1), 6-11. doi: 10.5772/14741

Hoagland, D. R., & Arnon, D. I. (1950). *The water-culture method for growing plants without soil*. (2nd ed.). (Circular. California agricultural experiment station, 347). Berkeley: University of California.

Hu, Y., Ye, X., Shi, L., Duan, H., & Xu, F. (2010). Genotypic differences in root morphology and phosphorus uptake kinetics in Brassica napus under low phosphorus supply. *Journal of Plant Nutrition, 33*(6), 889-901. doi: 10.1080/01904161003658239

Hussain, M. Z., Rehman, N., Khan, M. A., Roohullah, M., & Ahmed, S. R. (2006). Micronutrients status of Bannu basen soils. *Sarhad Journal of Agriculture, 22*(2), 283-285.

Jahiruddin, M., Ali, M. S., Hossain, M. A., Ahmed, M. U., & Hoque, M. M. (1995). Effect of boron on grain set, yield and some others of wheat cultivars. *Bangladesh Journal of Agricultural Sciences, 22*(1), 179-184.

Jha, D. P., Sharma, S., & Amarawat, T. (2015). Effect of organic and inorganic sources of nutrients on yield and economics of black gram (*Vigna mungo* L.) grown during kharif. *Agricultural Science Digest-A Research Journal, 35*(3), 224-228. doi: 10.5958/0976-0547.2015.00052.X

Johansen, C., Musa, A. M., Kumar, J. V. D. K., Harris, D., Ali, M. Y., Shahidullah, A. K. M., & Lauren, J. G. (2007). Correcting molybdenum deficiency of chickpea in the High Barind Tract of Bangladesh. *Journal of Plant Nutrition and Soil Science, 170*(6), 752-761. doi: 10.1002/jpln.200700249

Kannan, S. (2010). Foliar fertilization for sustainable crop production. In E. Lichtfouse (Ed.), *Genetic engineering, biofertilisation, soil quality and organic farming* (pp. 371-402). Dordrecht: Springer. doi: 10.1007/978-90-481-8741-6_13

Kerin, V., & Berova, M. (2003). Foliar fertilization in plants. *Videnov and Son, Sofia.* Bulgarian.

Khan, M. A., Fuller, M. P., & Baluch, F. S. (2008). Effect of soil applied zinc sulphate on wheat (*Triticum aestivum* L.) grown on calcareous soil in Pakistan. *Cereal Research Communication, 36*(4), 571-582. doi: 10.1556/crc.36.2008.4.6

Krishnaveni, S., Anandha, A., Palchamy, A., & Mahendran, S. (2004). Effect of foliar spray of nutrients on growth and yield of green gram (*Phaseolus radiatus*). *Legume Research an International Journal, 27*(2), 149-150.

Kuepper, G. (2003). *Foliar fertilization.* Butte City: ATTRA - National sustainable Agriculture Information service. NCAT Agriculture specialist.

Law-Ogbomo, K. E., & Egharevba, R. K. A. (2009). Effects of planting density and NPK fertilizer application on yield and yield components of tomato (*Lycospersicon esculentum* Mill.) in forest location. *World Journal of Agricultural Sciences, 5*(2), 152-158. doi: 10.1.1.415.1940

Li, H. Z., & Cheng, Z. H. (2015). Hoagland nutrient solution promotes the growth of cucumber seedlings under light-emitting diode light. *Acta Agriculturae Scandinavica Section B-Soil and Plant Science, 65*(1), 74-82. doi: 10.1080/09064710.2014.967285

Liu, F., Andersen, M. N., & Jensen, C. R. (2003). Loss of pod set caused by drought stress is associated with water status and ABA content of reproductive structures in soybean*. Functional Plant Biology, 30*(3), 271-280. doi: 10.1071/FP02185

Maneetong, S., Chookhampaeng, S., Chantiratikul, A., Chinrasri, O., Thosaikham, W., Sittipout, R., & Chantiratikul, P. (2013). Hydroponic cultivation of selenium-enriched kale (*Brassica oleracea var. alboglabra* L.) seedling and speciation of selenium with HPLC–ICPMS. *Microchemical Journal, 108*(1), 87-91. doi: 10.1016/j.microc.2013.01.003

Muehlbauer, F. J., & Sarker, A. (2017) Economic Importance of Chickpea: Production, Value, and World Trade. In R. Varshney, M., Thudi, & F. Muehlbauer (Eds.), *The Chickpea Genome*. Compendium of Plant Genomes. Springer, Cham. doi: 10.1007/978-3-319-66117-9_2

Nublat, A., Desplans, J., Casse, F., & Berthomieu, P. (2001). Arabidopsis mutant over accumulating sodium in the shoot shows deficiency in the control of the root radial transport of sodium. *The Plant Cell, 13*(1), 125-137. doi: 10.1105/tpc.13.1.125

Okweche, S. I., & Avav, T. R. (2013). Yield evaluation of some cultivars of mungbean (*Vigna radiata* (L) Wilczek) in southern guinea savanna location of Nigeria. *International Journal of Plant, Animal and Environmental Sciences*, *3*(3), 85-88. Recovered from http://www.ijpaes.com/.../357_pdf.pdf

Rahim, M. A., Mia, A. A., Mahmud, F., & Afrin, K. S. (2008). Multivariate analysis in some mungbean (*Vigna radiata* L. Wilczek) accessions on the basis of agronomic traits. *American-Eurasian Journal of Scientific Research, 3*(2), 217-221. doi: 10.1.1.489.8516

Rahman, I. U., Afzal, A., Iqbal, Z., Ijaz, F., Sohail, S. S., Manan, S., & Afzal, M. (2014). Response of common bean (*Phaseolus vulgaris*) to basal applied and foliar feeding of different nutrients application. *American-Eurasian Journal of Scientific Research, 14*(9), 72-75. doi: 10.5829/idosi.aejaes.2014.14.09. 12400

Sadeghi, S. M., & Noorhosseini, S. A. (2014). Evaluation of foliar application effects of Zn and Fe on yield and its components of lentil (*Lens culinaris*, medik), Iran. *Indian Journal of Fundamental and Applied Life Sciences, 4*(2), 220-225. Recovered from http://www.cibtech.org/J%20LIFE%20SCI

Sahai, V. N. (2004). Mineral Nutrients. *Fundamentals of Soil* (3rd ed. pp. 151-155). Kalyani Publishers, New Dehli,

Salih, H. O. (2013). Effect of foliar fertilization of Fe, B and Zn on nutrient concentration and seed protein of cowpea "*Vigna Unguiculata*". *Journal of Agriculture and Veterinary Sciences, 6*(3), 42-46. doi: 10.9790/2380-0634246

Sarwar, R. A., Ashraf, M., & Javaid, M. M. (2018). Response of foliar-applied nutrient solution with and without soil-applied fertilizers on growth and yield of mung bean. *Journal of Plant Nutrition*, *41*(9), 1083-1093. doi: 10.1080/01904167.2017.1381722

Schwabe, F., Schulin, R., Limbach, L. K., Stark, W., Burge, D., & Nowack, B. (2013). Influence of two types of organic matter on interaction of CeO2 nanoparticles with plants in hydroponic culture. *Chemosphere, 91*(4), 512-520. doi: 10.1016/j.chemosphere.2012.12.025

Shahid, M. A., Pervez, M. A., Balal, R. M., Abbas, T., Ayyub, C. M., Mattson, N. S.,… Iqbal, Z. (2012). Screening of pea (*Pisum sativum* L.) genotypes for salt tolerance based on early growth stage attributes and leaf inorganic osmolytes. *Australian Journal of Crop Science, 6*(9), 1324-1331. Recovered from https://search.informit.com.au/documentSummary;dn=732358544071642;res=IELHSS

Singh, H. P., Ramakrishna, Y. S., Sharma, K. L., & Venkateswarlu, B. (1999). *Fifty years of dryland agriculture research in India.* Hyderabad: Central Research Institute for Dryland Agriculture.

Steel, R. G. D., Torrie, J. H., & Dicky, D. (1997). Principles and Procedures of Statistics. *Multiple comparison* (3rd ed. Pp. 178-198). McGraw Hill Book Co., New York.

Taiz, L., & Zeiger, E. (2009). *Fisiologia vegetal* (4nd ed.). Porto Alegre: Editora ARTMED.

Turner, N. C. (2004). Adaptation to drought: lessons from studies with chickpea. *Indian Journal of Plant Physiology, 9*(1), 11-17. Recovered from https://dialnet.unirioja.es/servlet/articulo?codigo=3278217

Valenciano, J. B., Boto, A., & Marcelo, V. (2010). Response of chickpea (*Cicerarientinum* L.) yield to zinc, boron, and molybdenum application under pot conditions. *Spanish Journal of Agricultural Research, 8*(3), 797-807. Recovered from https://dialnet.unirioja.es/servlet/articulo?codigo=3278217

Waheed, H., Javaid, M. M., Shahid, A., Ali, H. H., Nargis, J., & Mehmood, A. (2019). Impact of foliar-applied Hoagland's nutrient solution on growth and yield of mash bean (*Vigna mungo* L.) under different growth stages. *Journal of Plant Nutrition*, *42*(10), 1133-1141. doi: 10.1080/01904167.2019. 1607380

Zain, M., Khan, I., Qadri, R. W. K., Ashraf, U., Hussain, S., Minhas, S.,… Bashir, M. (2015). Foliar application of micronutrients enhances wheat growth, yield and related attributes. *American Journal of Plant Sciences, 6*(7), 864-869. doi: 10.4236/ajps.2015.67094