Foliar application of potassium and moringa leaf extract improves growth, physiology and productivity of kabuli chickpea grown under varying sowing regimes

Sohail Irshad1,*, Amar Matloob1, Shahid Iqbal1,2, Danish Ibrar3, Zuhair Hasnain4, Shahbaz Khan3, Nabila Rashid5, Muhammad Nawaz6, Rao Muhammad Iqram1, Muhammad Ashfaq Wahid7, Abdulrahman Al-Hashimi8, Mohamed S. Elshikh8, Zeng-Hui Diao9*

1 Department of Agronomy, MNS-University of Agriculture, Multan, Pakistan, 2 Department of Plant and Environmental Sciences, University of Copenhagen, Copenhagen, Denmark, 3 National Agricultural Research Center, Islamabad, Pakistan, 4 Department of Agronomy, PMAS- Arid Agriculture University, Rawalpindi, Pakistan, 5 Department of Botany, University of Agriculture, Faisalabad, Pakistan, 6 Department of Agricultural Engineering, KFUET, Rahim Yar Khan, Pakistan, 7 Department of Agronomy, University of Agriculture, Faisalabad, Pakistan, 8 Department of Botany and Microbiology, College of Science, King Saud University, Riyadh, Saudi Arabia, 9 Guangdong Provincial Engineering and Technology Research Center for Agricultural Land Pollution Prevention and Control, Zhongkai University of Agriculture and Engineering, Guangzhou, China

* sohailuaf99@gmail.com (SI); zenghuid86@163.com (Z-HD)

Abstract

Chickpea (Cicer arietinum L.) is of prime importance because of vital source of protein as major food legume. Globally, it is cultivated on large area to meet dietary requirements of humans. Climatic extremes (erratic rainfall, extreme high and low temperature) are key restraints for its production. Optimum sowing time is considered as an important factor to address climatic variations and to attain maximum yield. Foliar application of potassium (K) has also been reported to increase resistance against abiotic stresses. Similarly, exogenous application of plant based growth substances (bio-stimulants) like moringa leaf extract (MLE) are extensively used to enhance productivity of field crops. Therefore, current study was planned to evaluate the impact of foliar applied K and MLE on growth, physiology and productivity of kabuli chickpea cultivated under normal and late sowing dates. There were two sowing dates (normal sown; November 15 and late sown; December 15, 2020). Experiment was comprised of treatments i.e. control, water spray, foliar application of K at 1%, foliar application of MLE at 3% and combined application of K and MLE. Foliar applied K and MLE significantly improved physiological, biochemical and yield attributes of kabuli chickpea cultivated under normal and late sown conditions. Increase in growth and yield attributes like plant height, number of nodules per plant, nodules dry weight, branches and pods per plant, 100-grain weight, biological and grain yield were recorded in case of combined foliar application of K and MLE in normal and late sown chickpea. Maximum improvement in gas exchange attributes (stomatal conductance and transpiration rate), chlorophyll contents, antioxidants (catalase, superoxide dismutase and ascorbate peroxidase) and osmolytes (proline) were
Introduction

Pulses have emerged as the most important crops which have been grown by human beings since time immortal. They are also known as leguminous food crops throughout the globe. Cultivation of pulses play very crucial role in the economy of the country. Chickpea (Cicer arietinum) in one of the most economical important food legumes cultivated round the world [1] as it plays vital role in human nutrition [2]. It is rich source of protein (21%), carbohydrates (61%) and oil (2.2%) [3] and classified as highly nutritious and healthy food [4]. It helps in improving and sustaining soil fertility by nitrogen (N) fixation [5]. However, the productivity of chickpea is not sufficient to fulfill the protein requirement for ever increasing masses [6,7]. Its production is limited by a number of abiotic (frost damage, drought, terminal heat etc.) and biotic (diseases and weeds) stresses [8]. Most importantly, unpredictable climate change is the major constraint for chickpea production as it increases the frequency of drought and temperature extremes i.e. high (> 30°C) and low (< 15°C) temperatures which reduces grain yields considerably [9,10].

Sowing time and techniques of any crop are mainly responsible for maximum growth and yield because it is an interaction of variety with its environment [11,12]. Flowering is an important phenomenon which has crucial role in final yield of crop and its development is more prone to environmental variations. Increase in temperature at flowering stage of chickpea is main cause of flower abortion [13]. Temperature is one of the critical factor causes flower abortion of chickpea when it exceeds more than 35°C [14]. Sowing of chickpea at optimum time outcomes timely initiation of flowering that minimize the impact of terminal heat and early cold stress resultantly better growth and development of chickpea plants [8]. Early sown chickpea results in lodging of crop, more disease incidence and drought stress at grain filling stage while late sown chickpea is more prone to insect attack, less vegetative cover and reduced water use efficiency [15]. Farmers have wrong perception that being legume crop, there is no nutritional requirements of chickpea and it is grown on marginal lands without any proper nutrition. Proper nutrition has significant role in improving growth and yield of pulses [16].

A set of physio-chemical, biological and integrated approaches is available for reducing yield losses [17–19]. Among them, the use of organic (biostimulants) and inorganic (nutrient and chemical agents) growth stimulators are considered viable approaches to compensate yield losses [19,20]. Biostimulants are natural growth enhancers that stimulate crop yield via enhanced nutrient uptake and efficiency, improved tolerance to biotic and abiotic stresses and enhancement of the rhizospheric activities [21]. Natural sources like seaweed extracts, protein hydrolysates and amino acids, humic acid, fulvic acid, complex organic materials, chitin and chitosan derivatives, microbial inoculants, biochar and plant extracts are the most commonly used biostimulants in agriculture [21–23]. Moringa oleifera leaf extract, sorghum water extract and mulberry water extracts are commonly used growth enhancers when applied as a seed priming agent and/or foliar spray [24,25]. It has been scientifically proven that they positively modify plant growth and production with alterations in metabolic processes under different cultivation practices [25–28]. Rehman et al. [29] also reported that application of plant growth promoters in combination with mineral elements improved the early growth, better establishment of seedlings and other yield contributing factors.

recorded with combined application of K and MLE in both sowing dates. Thus, combined applied K and MLE can be used to enhance productivity of kabuli chickpea.

Funding: The author(s) received no specific funding for this work.

Competing interests: The authors declare no any conflict of interest.
Moringa, among all the naturally occurring plant growth stimulants, has received enormous attention from the scientific community because of its rich source of growth hormones (zeatin), antioxidants, vitamins and mineral nutrients in its leaves [30]. Rashid et al. [31] and Makawita et al. [32] stated that foliage application of biostimulants i.e. sea weed extract, is good source of nutrient to uplift the crop productivity. Potassium (K) is major element which has important role in many plant processes [33] and its application is usually abandoned causing nutrient imbalances that reduce crop yields [34]. Foliar feeding of K improves enzymatic systems, water use efficiency, protein formation, nitrogen assimilation and photosynthesis [35]. Kumar and Rao [36] reported that an increase in the production of pulses was observed when K was applied at 20–40 kg K ha⁻¹. Younas et al. [37] also reported that external application of chemicals induces resistant against the diseases in field crops. Currently, farmers are conscious about inorganic fertilization to increase crop production and maintaining soil fertility but there is need to promote the use of organic fertilizers and explore safe, alternative and natural plant based nutrients [38–40]. Tabaxi et al. [41] also concluded that organic fertilization is also responsible for quantity as well as quality of produce cultivated under field conditions. Zahid et al. [42] confirmed that combined application of inorganic fertilizer like urea and poultry had prominent impact on plant height, leaf area, number of leaves per plant, fruit weight and postharvest quality of cucumber. Application of mineral elements in combination with organic compounds is a good agronomic practice to increase quality of field crops [43,44].

Foliar feeding or exogenous application of nutrients and organic compounds is very effective method to meet nutritional deficiencies, transmission of nutrients, quick and efectual use of nutrients and reduced leaching & fixation losses of nutrients [25,45]. Under water deficit conditions, foliar feeding of nutrients results in higher uptake of nutrients than soil application [46]. Number of studies has shown that foliar application can boost yield up to 12–25% and 90% of the nutrient applied is consumed by the plant [47]. Foliar feeding of nutrients at flowering and seed development is gaining extensive attention to increase seed yield in pulses. Hakoomat et al. [48] reported among various factors, weed management, latest production technology, high yielding varieties and balanced nutrition are of prime importance. Khan et al. [28] that application of MLE either alone or/and in combination with inorganic growth enhancer is responsible for improved growth and productivity of cereal crops particularly wheat as MLE application plays its role in crops to maintain water balance, membrane stability, boosts antioxidant activity, increase production of secondary metabolites and enhance crop performance [25,27,40]. Less information is available on foliar application of MLE in combination with potassium on growth and productivity of chickpea. Keeping in view the above rational, current study was planned to evaluate the impact of foliar application of K and MLE either sole or/and in combination on growth and productivity of chickpea cultivated under varying sowing regimes (normal sown and late sown chickpea).

**Materials and methods**

**Experimental particulars**

The planned study was conducted at the Research Area, MNS-University of Agriculture, Multan, during rabi season of 2020–21. The experiment was laid out in randomized complete block design (RCBD) with split plot arrangement having three replications with a net plot size of 20 m² (5m × 4 m). Experimental soil was loam in texture and other details of physical-chemical attributes are presented in Table 1. Seedbed was thoroughly prepared by ploughing followed by planking after soaking irrigation. Seed of kabuli gram, cv. Noor 2013, was obtained from Ayub Agricultural Research Institute, Faisalabad-Pakistan. Crop was sown with the help of hand drill in 45 cm spaced rows and plant spacing of 15 cm using seed rate of 60 kg ha⁻¹.
Crop was sown on November 15, 2020 was considered as normal sowing while sown on December 15, 2020 was considered as late sowing.

The weather data, including maximum temperature, minimum temperature, mean temperature, relative humidity and rainfall, are presented in Fig 1. Fertilizers were applied at 32 and 85 kg ha\(^{-1}\) of phosphorus and nitrogen, respectively. All phosphorus was applied at the time of planting while nitrogen was applied in two splits, half the dose was applied at sowing time while the remaining was applied at 1\(^{st}\) irrigation after sowing of 45 days. Total three irrigations, at suitable intervals, were given till maturity. Other agronomic practices were kept normal and

| Physical and chemical properties of experimental soil. |
|------------------------------------------------------|
| Soil Analysis Unit Value                              |
| **Physical Characteristics**                         |
| Sand %                                                | 39 |
| Silt %                                                | 42 |
| Clay %                                                | 19 |
| Texture Class                                        | Loam |
| **Chemical Characteristics**                         |
| pH                                                   | 7.9 |
| EC dS m\(^{-1}\)                                      | 5.21 |
| Nitrogen me/l                                        | 0.0622 |
| Available phosphorus ppm                             | 7.9 |
| Potassium me/l                                       | 76 |
| Organic matter %                                     | 1.01 |

https://doi.org/10.1371/journal.pone.0263323.t001

Fig 1. Weather data of the experimental station during 2020–2021 growing season of crop.

https://doi.org/10.1371/journal.pone.0263323.g001
uniform. Necessary plant protection measures were adopted to keep crop free of weeds, insects and diseases.

**Treatments plan and extract preparation**

Study was planned with two sowing dates (normal and late) and comprised of following treatments i.e. control, water spray, foliar application of K at 1%, foliar application of MLE at 3% and combined foliar application of K and MLE. All the treatments were foliar applied at flowering stage. Source of K was KCl and for 3% MLE preparation protocol was adopted as prescribed by Khan *et al.* [28]. For MLE extraction, healthy, fresh and mature leaves from moringa tree were collected. Leaves were thoroughly rinsed with tap water and were placed in refrigerator for a night. Extract was prepared using locally assembled machine and dilution of extract was made consuming distilled water to prepare 3% solution.

**Chlorophyll pigment and gas exchange attributes determination**

Data regarding chlorophyll pigment and gaseous exchange attributes were recorded after one week of treatment’s application. Chlorophyll contents of leaves were measured using SPAD (502 plus) and data were recorded from three tagged plants in each treatment plot and mean value was calculated. For data collection, flag leaf was used for estimation stomatal conductance \((g_s)\) (mmol m\(^{-2}\) s\(^{-1}\)) and transpiration rate \((E)\) (mmol H\(_2\)O m\(^{-2}\) s\(^{-1}\)) were assessed by following the standard protocols prescribed by Long *et al.* [49] using an infrared gas analyzer (IRGA) ADC Bio-Scientific Ltd. LI-6400 portable device.

**Enzymatic and quality attributes**

Data regarding antioxidant enzymatic activity and osmolytes were also determined after one week of treatment’s application. The SOD activity was measured according to Giannopolitis and Ries [50]. The activity of CAT was recorded by using spectrophotometer with the performance set according to Chance and Maehly [51]. Ascorbate peroxidase (APX) activity was estimated according to Nakano and Asada [52] with slight modification. Free proline in leaf tissues was appraised by following the protocol of Bates *et al.* [53]. The K\(^+\) concentration in grain was measured by using flame photometer (Sherwood, UK, Model 360) according to the standard procedure of USDA, Laboratory Staff [54]. For protein determination, seed nitrogen was analyzed using Kjeldahl method [55]. Percent crude protein was calculated using acid based titration and volume of acid used was multiplied by 6.25.

**Agronomic and yield attributes**

Plant height and number of branches per plant were recorded at maturity. Plant height was measured from three randomly selected plants with the help of meter rod and their branches were counted manually. Data regarding number of nodules were recorded at 60 days after sowing, for this purpose three randomly plants were uprooted carefully, washed and their nodules were separated from roots and counted. These nodules then oven dried till constant weight to get the data of nodules dry weight by using electronic weighing balance. For the estimation of number of pods per plant, five plants were randomly selected from each experimental unit after harvesting and their pods were counted. At maturity, whole plants with grains were harvested from 1 m\(^2\) area, sun dried and weighed to get biological yield in kg and later converted to kg ha\(^{-1}\). 100-grain weight was recorded by weighing 100 grains from each experimental unit by using electronic weighing balance. Grain yield was determined by harvesting area of 1 m\(^2\) from each plot, weighed and then converted in kg ha\(^{-1}\). Harvest index was
calculated as it is the ratio of grain yield to total (above ground) biological yield expressed in percentage.

\[
\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100
\]

**Statistical analysis**

Compiled data related to growth, physiology and productivity were examined statistically using statistical package "Statistic 8.1". Fisher’s analysis of variance technique (ANOVA) was used for testing significance of collected data. For graphical presentation and estimation of standard errors Microsoft excel was used. Difference among treatment means was equated by employing HSD, Tukey’s test at the level of 5% probability [56].

**Results**

Significant levels of growth, gas exchange, osmolytes, enzymatic antioxidants activity, yield and quality parameters in response to foliar applied K and MLE in normal and late sown kabuli chickpea is presented in Table 2. Data regarding number of nodules, nodules dry weight and plant height are presented in Table 3. Highest value of nodules per plant were observed in normal sowing followed by late sowing. Maximum nodules per plant were observed in combined application of K and MLE followed by MLE, K, water spray and control while interaction of foliar treatments and sowing dates was non-significant. In case of nodules dry weight per plant, similar trend regarding sowing dates was observed while maximum value of nodules dry weight was observed in combined application of K and MLE which was statistically similar to sole application of MLE and minimum value was observed in control and interaction was non-significant. Regarding sowing dates, highest value of plant height was observed in case of normal sowing followed by late sowing. Regarding treatments, maximum value of plant height was observed in case of combined foliar application of MLE and K which is statistically similar to sole application of MLE and minimum value was observed in control (Table 3).

| SOV                  | Chl. | E   | Gs  | NdPP | NdDW | PH  |
|----------------------|------|-----|-----|------|------|-----|
| Treatments (T)       | 599.7** | 1.102** | 367.4** | 3.883NS | 9.653* | 113.2** |
| Sowing dates (S)     | 34.11* | 5.241* | 2231* | 8.533* | 297.1** | 785.4** |
| T × S                | 2.53NS | 0.073NS | 46.14** | 0.616NS | 0.470NS | 2.825NS |
| BPP                  | PP   | HGW | BY  | 263987** | 32982** | 19.49** |
| Treatments (T)       | 31.88** | 198.1** | 8.878** | 0.201** | 4.652** | 3.743** |
| Sowing dates (S)     | 229.6** | 554.7** | 2.465** | 80988** | 47326** | 7.518** |
| T × S                | 3.217NS | 1.783NS | 14.89** | 5.33* | 1.875* | 1.008NS |
| CAT                  | SOD  | APX | Proline | 0.017NS | 0.062NS | 0.044NS |
| Treatments (T)       | 43.84** | 63.82** | 14.89** | 5.33* | 4.652** | 7.518** |
| Sowing dates (S)     | 34.35* | 63.95* | 34.77* | 14.26** | 1.875* | 1.008NS |
| T × S                | 21.56** | 40.38** | 9.05** | 0.017NS | 0.062NS | 0.044NS |

SOV = Source of variance, Chl = Chlorophyll, E = Transpiration rate, gs = stomatal conductance, NdPP = Nodules per plant, NdDW = Nodules dry weight, PH = Plant height, BPP = Branches per plant, PP = Pods per plant, HGW = 100-grain weight, BY = Biological yield, GY = Grain yield, HI = Harvest index, CAT = Catalase, SOD = Superoxide dismutase, APX = Ascorbate peroxidase, GPC = Grain protein contents, GKC = Grain potassium contents NS = Non-significant, * = Significant at P ≤ 0.05, ** = Significant at P ≤ 0.01.

https://doi.org/10.1371/journal.pone.0263323.t002
Interaction of sowing dates and foliar treatments for plant height was statistically non-significant (Table 2).

Late sowing of chickpea significantly reduced the number of branches per plant as maximum branches were observed in normal sown crop (Table 4). Regarding foliar treatment, highest number of branches per plant were attained by combined application of K and MLE which was statistically similar to sole application of MLE followed by K. Minimum value was observed in case of control and interaction was non-significant. In case of number of pods per plant, similar trend was observed regarding sowing regimes. In case of foliar treatments, application of K+MLE produced maximum pods per plant followed by sole application of MLE and K. Highest value of 100-grain weight was attained in normal sowing of chickpea followed by late sowing. In case of foliar treatments, highest 100-grain weight was observed in combined application of K and MLE which was statistically similar to MLE followed by K. Interaction between sowing dates and foliar treatments was also found statistically significant. Combined application of K and MLE was responsible for maximum 100-grain weight of chickpea under normal sowing conditions.

Data regarding biological yield, grain yield and harvest index are presented in Table 5. In case of biological yield there was significant effect of foliar treatments and sowing dates as well as their interaction. Highest biological yield was attained in normal sowing of chickpea followed by late sowing. In case of foliar treatments, maximum value was in case of K+MLE which was statistically similar to MLE and minimum value was observed in case of control.

| Treatments | Nodules per plant | Nodules dry weight (mg) | Plant height (cm) |
|------------|-------------------|------------------------|-------------------|
|            | NS    | LS    | Mean (T) | NS    | LS    | Mean (T) | NS    | LS    | Mean (T) |
| Control    | 11.33 | 10.66 | 11.00A  | 38.66 | 32.43 | 36.55B  | 48.80 | 39.53 | 44.16C  |
| Water spray | 11.66 | 10.66 | 11.16A  | 39.00 | 33.50 | 36.25AB | 50.46 | 42.13 | 46.30C  |
| K 1%       | 13.33 | 11.33 | 12.53A  | 40.66 | 34.53 | 37.60AB | 56.63 | 45.50 | 51.06B  |
| MLE 3%     | 13.00 | 11.66 | 12.33A  | 41.33 | 34.33 | 37.83AB | 58.53 | 46.96 | 52.75AB |
| K + MLE    | 13.00 | 12.66 | 12.83A  | 42.00 | 35.40 | 38.70A  | 59.33 | 48.96 | 54.40A  |
| Mean (S)   | 12.46A| 11.40B| 12.03A  | 40.33A| 34.04B| 38.14A  | 54.85A| 44.62B| 49.58A  |

Means sharing the same letter did not differ significantly at P = 0.05, MLE = Moringa leaf extract, K = Potassium, S = Sowing date, T = Foliar treatments.

Table 4. Impact of foliar applied potassium and moringa leaf extract on number of branches per plant, number of pods per plant, and 100-grain weight of normal and late sown kabuli chickpea.

| Treatments | Branches per plant | Pods per plant | 100-grain weight (g) |
|------------|-------------------|---------------|----------------------|
|            | NS    | LS    | Mean (T) | NS    | LS    | Mean (T) | NS    | LS    | Mean (T) |
| Control    | 18.33 | 13.33 | 15.83B  | 45.33 | 38.33 | 41.83D  | 25.16e | 24.36f | 24.76E  |
| Water spray | 18.66 | 14.00 | 16.33B  | 49.00 | 39.33 | 44.16D  | 25.50e | 25.26e | 25.38D  |
| K 1%       | 19.33 | 15.33 | 17.33B  | 52.66 | 44.66 | 48.66C  | 26.66cd| 26.55cd| 26.60C  |
| MLE 3%     | 23.00 | 16.66 | 19.83A  | 56.33 | 47.00 | 51.66B  | 27.51b | 26.66cd| 27.09AB |
| K + MLE    | 25.00 | 17.33 | 21.16A  | 60.66 | 51.66 | 56.16A  | 28.15a | 27.28bc| 27.71A  |
| Mean (S)   | 20.86A| 15.33B| 20.33B  | 52.80A| 44.20B| 50.10A  | 26.60A | 26.02B| 26.38A  |

Means sharing the same letter did not differ significantly at P = 0.05, MLE = Moringa leaf extract, K = Potassium, S = Sowing date, T = Foliar treatments.
Under interaction circumstances, combined application of K and MLE produced highest biological yield under normal sowing conditions. In case of grain yield, highest value was observed in case of normal sowing followed by late sowing. Regarding foliar treatments, maximum value was observed in case of K+MLE application followed by MLE and K. Interaction between sowing dates and foliar treatments was also recorded significant. Interaction of sowing dates and foliar treatments regarding harvest index (HI) was recorded statistically significant. Maximum value of HI was observed by combined application of K and MLE under late sown conditions.

Data regarding impact of foliar applied K and MLE on chlorophyll contents and transpiration rate are presented in Fig 2. Highest concentration of chlorophyll was observed in normal sowing followed by late sowing. Combined application of K and MLE produced maximum concentration of chlorophyll which was statistically similar to alone application of MLE followed by K while minimum in control treatment. Fig 2 also represents the data regarding transpiration rate which was statistically significant. Normal sowing of chickpea represented highest value of transpiration rate followed by late sowing while, in case of foliar treatment, highest value was observed in case of K+MLE which was statistically similar to MLE followed by K. Data regarding stomatal conductance (gs) and ascorbate peroxidase (APX) activities are given in Fig 3. Maximum gs was recorded under normal sown by combined application of K and MLE followed by alone MLE and K under normal sowing. While lowest gs was observed in control treatment under late sowing.

Maximum activities of APX recorded under late sowing of chickpea by combined application of K and MLE followed by alone application MLE under late sowing (Fig 3). Fig 4 depicted the data regarding the activities of catalase (CAT) and superoxide dismutase (SOD) in chickpea cultivated under normal and late sown conditions in response to application of K and MLE. The interaction of foliar treatments and sowing date was observed statistically significant (Table 2). Maximum activity of CAT was analyzed by combined application of K and MLE under late sown conditions followed by alone MLE application under same sowing conditions. Minimum activity of CAT was recorded under control treatment. SOD activity was also recorded highest by combined application of K and MLE under late sown conditions.

Data regarding leaf proline, grain protein and grain potassium are expressed in Fig 5. All the foliar treatments significantly improved the proline concentration in leaf but maximum improvement was recorded by the combined application of K and MLE. In case of sowing regimes, maximum proline activity was analyzed under normal sowing of chickpea as compared to late sowing. Highest value of protein in grain was observed in case of normal sowing.

### Table 5. Impact of foliar applied potassium and moringa leaf extract on biological yield (kg/ha), grain yield (kg/ha) and harvest index of normal and late sown kabuli chickpea.

| Treatments     | Biological yield (kg/ha) | Grain yield (kg/ha) | Harvest index (%) |
|----------------|--------------------------|---------------------|-------------------|
|                | NS | LS | Mean (T) | NS | LS | Mean (T) | NS | LS | Mean (T) |
| Control        | 3136.0e | 2803.0g | 2969.5E | 1800.3d | 1528.7f | 1664.5D | 42.59e | 45.46c | 44.02B |
| Water spray    | 3255.0d | 2854.0dg | 3054.5D | 1904.3c | 1549.7e | 1727.0C | 41.49f | 45.70c | 43.59C |
| K 1%           | 3502.7c | 2965.7f | 3234.2C | 1916.3c | 1509.3f | 1712.8C | 45.29c | 49.10b | 47.19A |
| MLE 3%         | 3767.3b | 3007.7f | 3387.5B | 2107.0b | 1499.7f | 1803.3B | 44.07d | 50.14a | 47.11A |
| K + MLE        | 3899.0a | 3021.0f | 3460.0A | 2197.3a | 1502.0f | 1849.7A | 43.64d | 50.28a | 46.96A |
| Mean (S)       | 3512.0A | 2930.3B | 1985.1A | 1517.9B | 43.41B | 48.13A |
| HSD            | S = 37.88, T = 33.20, S×T = 55.817 | S = 33.39, T = 17.85, S×T = 74.06 | S = 0.537, T = 0.318, S×T = 1.1978 |

Means sharing the same letter did not differ significantly at P = 0.05, MLE = Moringa leaf extract, K = Potassium, S = Sowing date, T = Foliar treatments.

https://doi.org/10.1371/journal.pone.0263323.t005
as compared to late sowing. Combined application of K and MLE produced maximum K concentration in chickpea grains followed by alone application of K. Minimum K concentration was found under control and water spray application. Late sowing of chickpea significantly reduced the K concentration in chickpea grains (Fig 5).

Discussion

Results of current study revealed that combined application of K and MLE increased gas exchange, biochemical attributes, growth and yield of normal and late sown kabuli chickpea. Significant increase in different growth and yield attributes like plant height, nodules per plant, nodules dry weight, branches and pods per plant was found by combined application of K and MLE while in case of sowing dates normal sowing performed better than late sowing. Number of scientists put forth the impact of sowing dates on yield and yield related attributes in chickpea [57]. Timely sowing resulted in better growth and yield while late sown chickpea after 15th November, ensued poor stand and short life span because of adverse climatic conditions [58]. Harvesting period and weather conditions had a significant impact on produce as
well as its quality [59]. Our findings are in agreement with Kabier et al. [60] who reported an increase in plant height in normal sown chickpea due to increased vegetative growth because of promising weather conditions as compared to late sowing. Similar results were testified by Mansur et al. [61] who reported that maximum number of branches per plant in case of early sown (15 November) and lowest branches of chickpea were in late sowing (30 November) were observed. Number of pods per plant is an important yield contributing factor which was also affected by sowing dates. Highest pods were noted in early sowing as compared to late sowing. Imran et al. [62] reported that exogenous application of nitrogenous fertilizer increased the plant height, grains per cob and economical yield of maize hybrids. Our findings are in line with Dixit et al. [63] and Siddique and Sedgley [64] who reported a decrease in number of pods per plant in case of late sown chickpea. Regarding foliar applied treatments MLE alone and in combination with K significantly affected yield attributes in current study. Foliar application of MLE can improve crop performance by enhancing water status, membrane stability, enzyme system and growth of plant [65]. Foliar applied K has advantage of

Fig 3. Impact of foliar applied K and MLE on stomatal conductance and ascorbate peroxidase activity of early and late sown kabuli chickpea.

https://doi.org/10.1371/journal.pone.0263323.g003
correcting K deficiency quickly in plant in late sowing as compared to soil application [66] as it involved in many plant physiological processes, enzyme activation, assimilation and photosynthesis and has direct impact on productivity of crop [67]. Farooq et al. [68] confirmed that foliar applied brassica water extract significantly improved the seedling characteristics like shoot/root biomass, shoot/root length and number of leaves in chickpea and yielded maximum. Findings of our study affirmed the reports of Asif et al. [69] who reported an increase in plant height, nodules per plant, number of secondary branches, pods per plant and grain yield chickpea (CM 98) by K application at varying rates. Ganga et al. [70] also confirmed our findings. Combined application of K and MLE improved overall growth and yield attributes which might be due to maximum availability of nutrients, growth promoting hormones that increased enzymatic activity, photosynthetic rate and various biochemical processes [71]. Our findings are in accordance with Yasmeen et al. [72] who reported an increase in plant height, number of branches and number of bolls, boll weight with combined foliar application of K and MLE. Increase in number of pods per plant might be due to more availability of K and other nutrients form foliar application of MLE which contains growth promoting hormone i.e. zeatin that improved pod formation, these results are in line with the findings of Moyo et al.
Exogenous application of mineral elements improved the growth and quality of produce in maize crop [74]. Other yield contributing attributes like 100-grain weight, biological yield, grain yield and harvest index were increased by foliar application of K and MLE in both sowing dates but kabuli chickpea performed better in normal sowing than late sowing. Overall improvement in yield attributes in normal sown kabuli chickpea is because of favorable environmental conditions as compared to late sown conditions. These findings are quite similar with the results of Ganguly and Bhattacharya [75] who reported sowing time effects the growth and development of chickpea and reported decrease in different morpho-physiological characteristics with late sowing due to unfavorable climatic conditions. Mohammadnejad and Soltani [76] reported an increase in yield contributing attributes (100-grain weight, biological yield, harvest index and grain yield) in case of early planting. Significant increase in yield and yield attributes of

Fig 5. Impact of foliar applied K and MLE on leaf proline (a), grain protein (b) and grain potassium contents of early and late sown kabuli chickpea.

https://doi.org/10.1371/journal.pone.0263323.g005
chickpea were observed in case of early planting as compared to late sowing [77]. In case of foliar applied K and MLE our results are similar to Goud et al. [78] who reported an increase in yield and yield related attributes like 100-grain weight, biological yield and grain yield with the application of K in chickpea. Similar results were also reported by Ganga et al. [70] who stated that an increase in 100-seed weight, seeds per pod, biological yield and grain yield by K application. Regarding the foliar application of K and MLE, all yield related attributes were enhanced. Improved yield and yield attributes might be due to fact that there was more availability of nutrients, supply of K, growth hormone, various micronutrients, phytohormones, growth boosting substances (ascorbic acid, phenols and minerals), cytokinin and gibberellic acid from MLE [79]. Our results are in line with the findings of Chattha et al. [80] and Yasmeen et al. [81] who reported that an increase in grain weight and grain yield was recorded by the application of MLE. Moreover, Mathew [82] and Ahmad et al. [83] also attained better crop yield by the application of MLE. Our findings also corroborated the results of Afzal et al. [84] who found an improvement in yield of late sown wheat by the foliar application of 3% MLE at tillering and booting stage. Our findings are similar to the results of Yasmeen et al. [72] who reported increase in boll weight, biological yield and lint yield in case of combined foliar application of K and MLE in cotton. Application of organic fertilizer improve the fertility status of soil with enhanced productivity of crops under stress conditions [85].

An increase in chlorophyll contents was also observed in chickpea by combined application of K and MLE followed by sole foliar application of MLE under sowing regimes in the current study. It might be due the fact that foliar application of K and MLE enhanced the nutrient availability, photosynthetic efficiency, carbohydrate synthesis and translocation. A decrease in chlorophyll contents in late sowing is due to short growth period and unfavorable environmental conditions. Our results are in line with the findings of Xu and Huang [86] who reported the decrease in chlorophyll contents and many physiological damages due to late sowing because of unfavorable environmental conditions like terminal heat stress in cool season crops. Regarding the foliar applied K and MLE, findings of current study are in accordance with Azeem and Ahmad [87] who reported that leaf chlorophyll contents were increased in tomato by foliar application of sole MLE and in combination of K, Fe and B. Similar findings related to our study were also reported by Mona [88] who stated that foliar application of MLE increased chlorophyll contents in Erusa vesicaria. Increment in gas exchange attributes antioxidant activities by foliar application of sole MLE, K and MLE, might be due to the presence of different allelochemicals and various secondary metabolites like phenols, ascorbate [30] and zeatin [89]. Our results are in line with the findings of Mona [88] and Abdalla [90] who reported increase in transpiration rate and stomatal conductance by foliar application of MLE in Erusa vesicaria. The boost in proline contents is due to the fact that MLE and K increased different organic solutes like soluble proteins, free amino acids and soluble sugars that ameliorate the negative impact of climatic conditions in late sown conditions [91]. Our results regarding antioxidants’ activities confirmed the findings of Rady et al. [65] who reported that foliar application of MLE alone in combination with other nutrients can maintain water status and avoid membrane damage, activate plant defense system and increase antioxidant levels in plant. Jan et al. [92] also reported an increase in antioxidant enzymatic activities like superoxide dismutase, ascorbate peroxidase and catalase by foliar feeding of K in combination with biostimulants. Increase in protein and K contents in sole K, MLE and combined K with MLE might be due the enhanced availability and absorption of various minerals and nutrients present in MLE that augmented the source efficiency of leaves. Our results are in agreement with Anantharaj and Venkatesalu [93] who reported that proteins contents were increased by the use of MLE that boosted absorption and translocation of minerals and nutrients. Rehman et al. [29] also reported that application of plant growth promoters in combination with
mineral elements improved the early growth, better establishment of seedlings and other yield contributing factors.

**Conclusion**

Foliar applied MLE and K sole and in combination significantly affected growth, physiological, biochemical, quality and yield attributes of kabuli chickpea cultivated under normal and late sown conditions. However, combined foliar application of K and MLE showed maximum increase in growth, physiological, gas exchange, biochemical, enzymatic activities, yield and quality attributes of kabuli chickpea grown under normal and late sown conditions. Hence, it is concluded from the findings of current study that foliar application of K and MLE at flowering stage can be boost growth and yield of kabuli chickpea cultivated under normal and late sown conditions.

**Acknowledgments**

The authors extend their appreciation to the Researcher Supporting Project number (RSP-2021/219), King Saud University, Riyadh, Saudi Arabia. This work was supported by the Special project in key areas of Guangdong Province Ordinary Universities (Nos. 2020ZDZX1003 and 2021ZDJJ007), the Key Realm R&D Program of Guangdong Province (Nos. 2020B1111350002 and 2020B0202080002), the Guangdong Provincial Special Fund for Modern Agriculture Industry Technology Innovation Teams (No.2019KJ140) and the National Natural Science Foundation of China (No.21407155).

**Author Contributions**

**Conceptualization:** Sohail Irshad, Shahbaz Khan, Muhammad Ashfaq Wahid.

**Data curation:** Sohail Irshad, Danish Ibrar, Shahbaz Khan, Rao Muhammad Ikram.

**Formal analysis:** Sohail Irshad, Danish Ibrar, Zuhair Hasnain, Shahbaz Khan, Muhammad Nawaz, Rao Muhammad Ikram, Muhammad Ashfaq Wahid, Mohamed S. Elshikh.

**Funding acquisition:** Abdulrahman Al-Hashimi, Mohamed S. Elshikh, Zeng-Hui Diao.

**Investigation:** Sohail Irshad, Shahbaz Khan, Nabila Rashid, Abdulrahman Al-Hashimi, Zeng-Hui Diao.

**Methodology:** Sohail Irshad, Shahbaz Khan, Nabila Rashid.

**Project administration:** Sohail Irshad, Amar Matloob, Shahid Iqbal, Shahbaz Khan, Zeng-Hui Diao.

**Resources:** Sohail Irshad, Amar Matloob, Danish Ibrar, Zuhair Hasnain, Shahbaz Khan, Nabila Rashid, Muhammad Nawaz, Rao Muhammad Ikram, Muhammad Ashfaq Wahid, Mohamed S. Elshikh.

**Software:** Sohail Irshad, Danish Ibrar, Zuhair Hasnain, Shahbaz Khan, Nabila Rashid, Muhammad Nawaz, Abdulrahman Al-Hashimi, Mohamed S. Elshikh, Zeng-Hui Diao.

**Supervision:** Sohail Irshad, Amar Matloob, Shahid Iqbal, Shahbaz Khan, Abdulrahman Al-Hashimi, Mohamed S. Elshikh, Zeng-Hui Diao.

**Validation:** Sohail Irshad, Amar Matloob, Shahid Iqbal, Zuhair Hasnain, Shahbaz Khan, Muhammad Ashfaq Wahid.
References

1. Rani A., et al., Developing Climate-Resilient Chickpea Involving Physiological and Molecular Approaches with a Focus on Temperature and Drought Stresses. Frontiers in Plant Sciences, 2020. 10: p. 1759–71. https://doi.org/10.3389/fpls.2019.01759 PMID: 32161601
2. Jaleel C., et al., Drought stress in plants: a review on morphological characteristics and pigments composition. International Journal of Agriculture and Biology, 2009. 11: p. 100–105.
3. Gupta YP., Nutritive value of pulses. In: Pulse Crop Baldev. Rawanujam S. and Jain H.K. (Eds.). Oxford IBH Publishing Co. Pvt. Ltd. New Delhi. 1988. p. 561–601.
4. Merga B. and Haji J., Economic importance of chickpea: Production, value, and world trade. Cogent Food and Agriculture, 2019. 5: e1615718.
5. Khaltov B., et al., Effect of chickpea in association with Rhizobium to crop productivity and soil fertility. Eurasian Journal of Soil Science, 2016. 5: p. 105–112.
6. Chaturvedi S.K., et al., Technological and policy intervention for increasing chickpea production in India. Pulse India, 2018. 8: p.7–12.
7. Henchion M., et al., Future protein supply and demand: strategies and factors influencing a sustainable equilibrium. Foods, 2017. 6: p. 1–21. https://doi.org/10.3390/foods6070053 PMID: 28726744
8. Whish J.P.M., Castor P. and Carberry P.S., Managing production constraints to the reliability of chickpea within marginal areas of the northern grains region of Australia. Australian Journal of Agricultural Research, 2007. 58: p. 396–405.
9. Gaur P.M., et al., Breeding achievements. Chickpea Breeding Management, 2007. 55: p. 391–416.
10. Kadiyala M.D.M., et al., Agronomic management options for sustaining chickpea yield under climate change scenario. Journal of Agrometeorology, 2016. 18: p. 41–47.
11. Knights E.J. and K.H.M. Siddique., Chickpea status and production constraints in Australia. In ‘Integrated management of botrytis grey mould of chickpea in Bangladesh and Australia. Summary Proceedings of a Project Inception Workshop, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh’. (Eds MA Bakr, KHM Siddique, C Johansen). 2002. pp. 33–41.
12. Rizwan M., et al., Effect of sowing techniques and tillage practices on paddy yield of direct seeded rice in salt affected soils. Asian Journal of Agriculture and Biology 2022: 202101043.
13. Singh K.B., Bejiga G. and Malhotra R.S., Associations of some characters with seed yield in chickpea collections. Euphytica. 1990. 93: p. 83–88.
14. Clarke H. and Siddique K.H.M., Growth and development in the Chickpea Book (eds. S. Loss, N. Brandon & K.H.M. Siddique), Agriculture Western Australia, Bulletin 1326; 1998. p. 112.
15. Matthews P. and McCaffery D., Winter crop variety sowing guide. NSW DPI Management Guide. 2011. P. 25.
16. Chandrasekhar C.N. and Bangararsamy U., Maximizing the yield of mung bean by foliar application of growth regulating chemicals and nutrients. Madras Agricultural Journal, 2003. 90: p. 142–145.
17. Bedada W., Lemenih M., Kartun E., Soil nutrient build-up, input interaction effect sand plot level N and P balances under long-term addition of compost and NP fertilizer. Agriculture, Ecosystems and Environment, 2016. 218: p. 220–231.
18. Gaudin A.C.M., et al., Increasing crop diversity mitigates weather variations and improves yield stability. PLoS ONE, 2015. 10: p. 1–20. https://doi.org/10.1371/journal.pone.0113261 PMID: 25658914
19. Khan S., et al., Combined application of moringa leaf extract and chemical growth-promoters enhances the plant growth and productivity of wheat crop (Triticum aestivum L.). South African Journal of Botany, 2020. 129: p. 74–81.

20. Batool S., Khan S. and Basra S.M.A., Foliar application of moringa leaf extract improves the growth of moringa seedlings in winter. South African Journal of Botany, 2020. 129: p. 347–353.

21. Jardin P.D., Plant biostimulants: definition, concept, main categories and regulation. Scientia Horticulturae, 2015. 196: p. 3–14.

22. European Biostimulants Industry Council., EBIC and Biostimulants in Brief. 2012. http://www.biostimulants.eu/.

23. Glodowska M., et al., Biochar is a growth-promoting alternative to peat moss for the inoculation of corn with a pseudomonad. Agronomy for Sustainable Development, 2016. 36: p. 21–31.

24. Khan S., et al., Screening of moringa landraces for leaf extract as biostimulant in wheat. International Journal of Agriculture and Biology, 2017. 19: p. 999–1006.

25. Batool S., et al., Impact of Natural and Synthetic Plant Stimulants on Moringa Seedlings Grown under Low-Temperature Conditions. International letters of Natural Sciences, 2019. 78: p. 50–59.

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

27. Rashid N., et al., Impact of Natural and Synthetic Growth Enhancers on the Productivity and Yield of Quinoa (Chenopodium quinoa Willd.) Cultivated under Normal and Late Sown Circumstances. Journal of Agronomy and Crop Science, 2021. 00: p. 1–15.

28. Khan S., et al., Growth promoting potential of fresh and stored Moringa oleifera leaf extracts in improving seedling vigor, growth and productivity of wheat crop. Environmental Science and Pollution Research, 2017. 24: p. 27601–27612. https://doi.org/10.1007/s11356-017-0336-0 PMID: 28980120

29. Rehman A., Hassan F., Qamar R. and Rehman A.U., Application of plant growth promoters on sugar-cane (Saccharum officinarum L.) budchip under subtropical conditions. Asian Journal of Agriculture and Biology, 2021. 202003202. https://doi.org/10.35495/ajab.2020.03.202

30. Foil N., Makkar H.P.S., Becker K., 2001. The potential of Moringa oleifera for agricultural and industrial uses. The miracle tree: The multipurpose attributes of moringa. CTA publications, Wageningen, the Netherlands, pp. 45–76.

31. Rashid N., et al., Exogenous application of moringa leaf extract improves growth, biochemical attributes, and productivity of late-sown quinoa. PLoS ONE, 2021. 16: e0259214. https://doi.org/10.1371/journal.pone.0259214 PMID: 34745570

32. Makawita G.I.P.S., Wickramasinghe I. and Wijesekara I., Using brown seaweed as a biofertilizer in the crop management industry and assessing the nutrient upliftment of crops. Asian Journal of Agriculture and Biology, 2021. https://doi.org/10.35495/ajab.2020.04.237

33. Sahai V.N., Mineral Nutrients. In Fundamentals of Soil. 3rd Edition. Kalyani Publishers, New Delhi, India. 2004. p. 151–155.

34. Memon M., et al., Response of chickpea cultivars to phosphorus application. Soil and Environment, 2016. 35: p. 22–29.

35. Hussain N., et al., Exogenously applied nutrients can improve the chickpea productivity under water stress conditions by modulating the antioxidant enzyme system. Brazilian Journal of Biology, 2021. 12: p. 82. https://doi.org/10.1590/1519-6984.236251 PMID: 34105664

36. Kumar J. and Rao B.V., Registration of ICCV 96029, a super early and double podded chickpea germplasm. Crop Science, 2001. 4: p. 605–606.

37. Younas M., et al., Induction of resistance in onion against purple leaf blotch disease through chemicals. Asian Journal of Agriculture and Biology 2021(4); 202001039. https://doi.org/10.35495/ajab.2020.01.039

38. Yasmeen A., Exploring the potential of Moringa oleifera leaf extract as natural plant growth enhancer. Department of Agronomy, University of Agriculture, Faisalabad, Pakistan. Thesis, 2011. p. 23–40.

39. Rashid N., et al., Exogenous Application of Biostimulants and Synthetic Growth Promoters Improved the Productivity and Grain Quality of Quinoa Linked with Enhanced Photosynthetic Pigments and Metabolomics. Agronomy, 2021. 11: p. 2302.

40. Khan S., et al., 2021. Moringa leaf extract improves biochemical attributes, yield and grain quality of rice (Oryza sativa L.) under drought stress. PLoS ONE, 2021 16: e0254452. https://doi.org/10.1371/journal.pone.0254452 PMID: 34270569

41. Tabaxi I., et al., Effect of organic fertilization on quality and yield of oriental tobacco (Nicotiana tabacum L.) under Mediterranean conditions. Asian Journal of Agriculture and Biology, 2021(1). https://doi.org/10.35495/ajab.2020.05.274
42. Zahid N, et al., Integrated effect of urea and poultry manure on growth, yield and postharvest quality of cucumber (Cucumis sativus L.). Asian Journal of Agriculture and Biology, 2021(1). https://doi.org/10.35495/ajab.2020.07.381

43. Rashid N., et al., Exogenous application of moringa leaf extract improves growth, biochemical attributes, and productivity of late-sown quinoa. PLoS ONE, 2021. 16: e0259214. https://doi.org/10.1371/journal.pone.0259214 PMID: 34748570

44. Hussan M.U., et al., Impact of soil applied humic acid, zinc and boron supplementation on the growth, yield and zinc translocation in wheat. Asian Journal of Agriculture and Biology, 2022(x): 202102080. https://doi.org/10.35495/ajab.2021.02.080

45. Manonmani V. and Srimathi P., Influence of Mother Crop Nutrition on Seed and Quality of blackgram. Madras Agricultural Journal, 2009. 96: p. 125–128.

46. Kirnapure V.S., et al., Influence of foliar application of nutrients on yield and economics of chickpea. Journal of Pharmacognosy and Phytochemistry, 2020. 9: 202–204.

47. Kachave T.R. and Kausadikar H.K., Impacts of Foliar Application of Speciality Fertilizers on nutrient uptake of Chickpea (Cicer arietinum L.). International Journal of Communication Systems, 2018. 6: p. 1699–1702.

48. Hakoomat A., Muhammad A.K. and Shakeel A.R., Interactive effect seed inoculation and phosphorus application on growth and yield of chickpea (Cicer arietinum L.). International Journal of Agriculture and Biology, 2004. 6: p. 110–122.

49. Long S.P., Farage P.K. and Garcia R.L., Measurement of leaf and canopy photosynthetic CO2 exchange in the field. Journal of Experimental Botany, 1996. 47: p. 1629–1642.

50. Giannopolitis C.N. and Ries S.K., Superoxide dismutase I. Occurrence in higher plants. Plant Physiology, 1977. 59: p. 309–314. https://doi.org/10.1104/pp.59.2.309 PMID: 16659839.

51. Chance B. and Maehly A.C., Assay of catalase and peroxidase. Methods in Enzymology, 1955. 2: p. 764–775.

52. Nakano Y. and Asada K., Purification of ascorbate peroxidase in spinach chloroplasts: its inactivation in ascorbate-depleted medium and reactivation by monodehydroascorbic acid. Plant and Cell Physiology, 1987. 28: p. 131–140.

53. Bates L.S., Waldren R.P. and Teare I.D., Rapid determination of free proline for water stress studies. Plant and Soil, 1973. 39: p. 205–207.

54. USDA Laboratory Staff., Diagnosis and Improvement of Saline and Alkali Soils. In Superintendent of Documents; Richards L.A., Ed.; U.S. Government Printing Office Washington: Washington, DC, USA. 1954. p. 45.

55. Bremer A.R., Organic forms of nitrogen. In: Methods of Soil Analysis, Part 2, ed. Black C.A., 1964. pp. 1235–1255. Madison, WI: American Society of Agronomy.

56. Steel R.G.D., Torrie J.H. and Dicky D.A., Principles and Procedures of Statistics, A biometrical approach. 3rd Ed. McGraw Hill, Inc. Book Co. NY (USA.) 1997. p. 352–358.

57. Chaitanya S.K. and Chandrika V., Performance of chickpea varieties under varied dates of sowing in chittoor district of Andhra Pradesh. Legume Research, 2006. 29: p. 137–139.

58. O’Toole N.F.L. and Stoddard O’Brien L., Screening of chickpea for adaptation to autumn sowing. Journal of Agronomy and Crop Science, 2001. 186: p. 193–207.

59. Rezouki S., et al., The impact of the harvesting period and drying conditions on the essential oil yield of Rosmarinus officinalis, Thymus satureoides and Origanum compactum from the Taza-Taounate region. Asian Journal of Agriculture and Biology, 2021(3): 202004251. https://doi.org/https%3A//doi.org/10.35495/ajab.2021.03.392

60. Kabier K., et al., Effect of sowing time and cultivars on the growth and yield of chickpea under rainfed condition. Bangladesh Journal of Agricultural Research, 2009. 34: p. 335–342.

61. Mansur CP., et al., Effect of dates of sowing and irrigation levels on biometric growth parameters of kabuli chickpea. Karnataka Journal of Agricultural Sciences, 2010. 23: p. 566–569.

62. Imran M., Ali A. and Safdar M.E., The impact of different levels of nitrogen fertilizer on maize hyibrids performance under two different environments. Asian Journal of Agriculture and Biology, 2021: 202010527. https://doi.org/10.35495/ajab.2020.10.527

63. Dixit J.P., Som N.K. and Namdeo K.N., Moisture-use pattern and yield of chickpea (Cicer arietinum L.) in relation to planting date, variety and irrigation. Indian Journal of Agronomy, 1993. 38: p. 573–577.

64. Siddique K.H.M. and Sedgley R.H., Chickpea (Cicer arietinum L.) a potential grain legume for southwestern Australia: seasonal growth and yield. Australian Journal of Agricultural Research, 1986. 37: p. 245–61.
65. Rady M.M., et al., Integrated application of salicylic acid and Moringa oleifera leaf extract alleviates the salt-induced adverse effects in common bean plants. Journal of Agricultural Technology, 2015. 11: p. 1595–1614.
66. Hassan Z.U. and Arshad M., Evaluating factors affecting cotton tolerance to potassium deficiency stress using path analysis. International Journal of Agriculture and Biochemistry, 2008. 10: p. 511–516.
67. Taiz L. and Zeiger E., Plant Physiology: Mineral Nutrition. The Benjamin Cummings Publishing Co., Inc. Redwood City, California, USA. 1991. p. 67.
68. Farooq O., et al., Foliar applied brassica water extract improves the seedling development of wheat and chickpea. Asian Journal of Agriculture and Biology, 2021. https://doi.org/10.35495/ajab.2020.04.219
69. Asif M., et al., Effect of phosphorus and potassium on the growth and yield performance of chickpea. Life Sciences: An International Journal, 2007. 1: p. 368–373.
70. Ganga N., et al., Effect of potassium level and foliar application of nutrient on growth and yield of late sown chickpea (Cicer arietinum L.). Environmental Ecology, 2014. 32: p. 273–275.
71. Sangakkara U.R., Frehner M. and Nosberger J., Effect of soil moisture and potassium fertilizer on shoot water potential, photosynthesis and partitioning of carbon in mung bean and cowpea. Journal of Agronomy and Crop Science, 2000. 185: p. 201–207.
72. Yasmeen A., et al., Economic analyses of sole and combined foliar application of moringa leaf extract (MLE) and K in growth and yield improvement of cotton. International Journal of Agriculture and Biology, 2018. 20: p. 857–863.
73. Moyo B., et al., Nutritional characterization of Moringa (Moringa oleifera L.) leaves. African Journal of Biotechnology, 2011. 10: p. 12925–12933.
74. Anwar Z., et al., Biofortification of maize with zinc and iron not only enhances crop growth but also improves grain quality. Asian Journal of Agriculture and Biology, 2022(x): 202102079. https://doi.org/10.35495/ajab.2021.02.079
75. Ganguly S.B. and Bhattacharya A., Effect of physiological traits on chickpea yield under normal and late seeding. Legume Research, 2001. 24: p. 6–10.
76. Mohammadnejad Y. and Soltani A., Shares of main stem and branches in determining grain yield of chickpea with different planting dates and densities. In proceeding of the First National Conference on Pulse in Iran. 20–21 November 2005. Research Center for Plant Sciences. Ferdowsi University of Mashhad. 2005. Mashhad. Iran.
77. Yucel D. and Anlarsal A.E. Performance of some winter chickpea (Cicer arietinum L.) genotypes in Mediterranean conditions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 2008. 36: p. 35–41.
78. Goud V.V., et al., Response of chickpea to potassium fertilization on yield, quality, soil fertility and economic in vertisols. Legume Research, 2014. 37: p. 311–315.
79. Makkar HPS., Francis G. and Becker K., Bioactivity of phytochemicals in some lesser known plants and their effects and potential applications in livestock and aquaculture production systems. Animal, 2007. 1: p. 1371–1391. https://doi.org/10.1017/S1751731107000298 PMID: 22444939
80. Chattha M.U., et al., Exogenous application of plant growth promoting substances enhances the growth, yield and quality of maize (Zea mays L.). Plant Knowledge Journal, 2015. 4: p. 1–6.
81. Yucel D. and Anlarsal A.E., Exogenous application of moringa leaf extract modulates the antioxidant enzyme system to improve wheat performance under saline conditions. Plant Growth and Regulation, 2013. 69: p. 225–233.
82. Mathew A., Moringa leaf extract on the growth and yield of Pepper (Capsicum annuum L.). Journal of Agriculture and Biological Sciences, 2016. 11: p. 107–109.
83. Ahmad W., et al., Improvement of sorghum crop through exogenous application of natural growth promoting substances under a changing climate. Sustainability, 2016. 8: p. 1330.
84. Afzal M.I., Ishbal M.A. and Cheema Z.A., Triggering growth and boosting economic yields of late-sown wheat (Triticum aestivum L.) with foliar application of allelopathic water extracts. World Journal of Agricultural Sciences, 2015. 11: p. 94–100.
85. Abd El-Fattah D.A., Hashem F.A. and Abd-Elrahman S.H., Impact of applying organic fertilizers on nutrient content of soil and lettuce plants, yield quality and benefit-cost ratio under water stress conditions. Asian Journal of Agriculture and Biology, 2022(x): 202102086. https://doi.org/10.35495/ajab.2021.02.086
86. Xu Y. and Huang B., Effects of foliar-applied ethylene inhibitor and synthetic cytokinin on creeping bentgrass to enhance heat tolerance. Crop Science, 2008. 45: p. 1876–1884.
87. Azeem M. and Ahmad R., Foliar application of some essential minerals on tomato (Lycopersicon esculentum) plant grown under two different salinity regimes. Pakistan Journal of Botany, 2011. 43: p. 1513–1520.
88. Mona M.A., The potential of Moringa oleifera extract as a biostimulant in enhancing the growth, biochemical and hormonal contents in rocket (Eruca vesicaria subsp. sativa) plants. International Journal of Plant Physiology and Biochemistry, 2013. 5: p. 42–49.

89. Fuglie L.J., The miracle tree: Moringa oleifera. Natural nutrition for the tropics. Church World Service, Dakar, Senegal, 1999. p. 68.

90. Abdalla M.M., The potential of Moringa oleifera extract as a bio-stimulant in enhancing the growth, biochemical and hormonal contents in rocket (Eruca vesicaria subsp. sativa) plants. International Journal of Plant Physiology and Biochemistry, 2013. 5: p. 42–49.

91. Abdel Latef A.A.H., et al., Foliar application of fresh moringa leaf extract overcomes salt stress in fenu-greek (Trigonella foenum-graecum) plants. Egyptian Journal of Botany, 2017. 57: p. 157–179.

92. Jan A.U., et al., Potassium and zinc increase tolerance to salt stress in wheat (Triticum aestivum L.). Plant Physiology and Biochemistry, 2017. 116: p. 139–149. https://doi.org/10.1016/j.plaphy.2017.05.008 PMID: 28558283

93. Anantharaj M. and Venkatesalu V., Effect of seaweed liquid fertilizer on Vigna catajung. Seaweed Research and Utilization, 2001. 23: p. 33–39.