J Agric. Res., 2017, Vol. 55(2):291-302
ISSN: Online: 2076-7897, Print:0368-1157
http://www.jar.com.pk

MITIGATING THE TERMINAL DROUGHT STRESS IN CHICKPEA (*CICER ARIENTINUM* L.) THROUGH EXOGENOUS APPLICATION OF NUTRIENTS

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ABSTRACT

A study was conducted at PMAS Arid Agriculture University, Rawalpindi, Khushab Campus, Pakistan during the year 2012-13. Terminal drought stress and low soil fertility are major constraints to harvest potential yield of rain-fed chickpea. Effect of exogenous application of K_2SO_4 (0.5, 1.0 and 1.5%) in combination with CAN (1, 2 and 3%) was investigated against terminal drought stress. Foliar spray of various combinations of CAN and K_2SO_4 were applied at 40 and 60 days after sowing of chickpea facing subsequent terminal drought stress using RCBD with three replications. Maximum pods per plant, 1000-grain weight, grain yield and biological yield were attained from 1.5% K_2SO_4 in combination with 2% or 3% CAN. Maximum number of grains per pod was harvested from 3% CAN in combination with 1.0 or 1.5% K_2SO_4. Significant delay in flowering was recorded from 3% CAN with 1.0 or 1.5% K_2SO_4. Exogenous application of 1.5% K_2SO_4 in combination with 2 or 3% CAN proved helpful in mitigating the terminal drought stress in chickpea.

KEYWORDS: *Cicer arietinum*; chickpea; terminal drought; nutrient application; calcium ammonium nitrate; Pakistan.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is an imperative food legume grown in the Mediterranean and semi-arid tropical regions, cultivated largely as a rainfed post-rainy season. The crop endures substantial yield loss due to terminal drought stress resulted by progressive receding conserved soil moisture (10). It is leading grain legume in Pakistan being cultivated on 1054 thousand hectares with annual production of 1096 thousand tons (3), with major contribution from Punjab province. In Punjab, it is predominately cultivated as

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rainfed crop in Thal region (Khushab, Mianwali, Bhakkar, Layya and Jhang districts) on sandy soils with residual soil moisture conserved during monsoon season (2).

Naturally, sandy soils of Thal are low in organic matter and deficient in nutrients. The problem is further aggravated by the fact that traditionally farmers of chickpea core areas of Thal are reluctant to use fertilizer due to high cost and narrow cost benefit ratio. Undoubtedly, judicial use of fertilizers had a significant effect on yield potential of pulses under rainfed conditions (1, 19). Nitrogen is an integral part of chlorophyll molecule and amino acids. Potassium is essential for maintenance of osmotic potential, stomatal closure and water uptake under drought conditions. Potassium activates wide range of enzymatic systems regulating water use efficiency, photosynthesis, nitrogen uptake and protein building (25). Similarly, chlorophyll formation and nitrogen fixing capacity of legumes is increased with adequate supply of sulfur (15). However, under drought conditions N, P, K, Mg, Ca, S, Zn, Fe, B and Mn uptake by roots of chickpea significantly decreases (12) resulting in yield losses.

Seed filling is, in part, dependable on nitrogen and carbon accumulated prior to pod setting. For example, as much as 90 percent of the seed nitrogen in *Cicer arietinum* subjected to terminal drought stress comes from pre-podding sources particularly leaves (9). Drought spells commenced before seed growth reduces photosynthetic efficiency of leaves and significantly reduces yield. Under these circumstances, the application of nitrogen fertilizer to the soil at pod setting and seed filling is ineffective to assist in delaying the withdrawal of nitrogen from leaves and sustaining leaf photosynthesis, since nitrogen is not taken up from the dry soil (22). To cope with this dilemma, exogenous application of nutrients is practiced as alternative to soil dressing, not only to improve yield but also to compensate deficient soil nutrients, as foliar feeding of nutrients had proven to be an exceptional method of supplying essential nutrients to plants (7).

Exogenous application of urea at various growth stages of chickpea resulted in a significant yield boost (5), While foliar applied nitrogen at flowering was shown to augment the seed yield and protein contents in chickpea subjected to terminal drought (22). Foliar application of K is known to improve drought tolerance of cereals and led to improved growth and yield components (4). Similarly, foliar application of potassium nitrate at vegetative growth stages had also augmented growth parameters, yields and yield components of pulses under drought conditions (25). Foliar applied calcium is usually immobile, but it can be induced to translocate in the leaf by chelation or by saturation of adsorption sites with divalent cations (13). Foliar application of 0.41% $Ca(NO_3)_2$ followed by 0.5% KNO_3 at 50 percent blooming proved to augment growth and yield attributes in rainfed lowland rice (*Oryza sativa*) (7). Similarly, chlorophyll fluorescence of the NaCl stressed plants of cowpea had showed higher values by foliar application of $Ca(NO_3)_2$, and suggested that Ca foliar application is partially effective in alleviating adverse effects of abiotic stress on these parameters (20), since, Ca^{2+} is an inorganic ion and makes great contribution in osmotic adjustment by ion transport processes with related ion antiporters and ion channels (8).

Most of the research conducted so far on exogenous application of nitrogen had employed urea as source of nitrogen. Whether applied by foliar application or in dry form, the Ammonium nitrate form of N is deemed superior to urea-N for mounting herbage yield, protein yield and crude-protein contents (14). Little literature is available on using commercial fertilizers calcium ammonium nitrate (CAN) as source of nitrogen and Ca^{+2}, and K_2SO_4 (sulphate of potash) as source of K^+ to augment drought stress.

The present study was planned to evaluate the potential of exogenous application of commercial fertilizers K_2SO_4 (SOP) and Calcium Ammonium Nitrate (CAN) to ameliorate terminal drought stress and compensate yield reduction in chickpea under conserved soil moisture and un-irrigated natural field conditions.

MATERIALS AND METHODS

A field experiment was carried out at PMAS Arid Agriculture University, Rawalpindi, Pakistan during 2012-13 Chickpea cultivar Bittal-98 was sown with single row hand drill in 30 cm apart rows on residual soil moisture conserved during rainy season (monsoon) using recommended seed rate (75 kg/ha). After seedling establishment, the plants were thinned and plant to plant distance of 15 cm was maintained. No supplementary irrigation was applied throughout the growing season of the crop, and the crop was protected from rain by using polythene sheath. Layout system was RCBD with three replications and net plot size of 3ft × 7 ft was maintained. All agronomic practices were kept uniform for all the treatments. No fertilizer was used other than exogenous application of K_2SO_4 and CAN. At time of sowing, the moisture contents of the field were at about 90 percent of field capacity. Light shower was applied to all treatments uniformly after 20 days of sowing.

Natural moisture depletion after 40 days and 60 days of sowing resulted in 73 percent (moderate drought stress) and 55 percent (severe drought stress) of field capacity, respectively. Tank mixture of 120 per acre was sprayed using flat fan nozzle at 40 psi at 40 days and 60 days after sowing. Data on plant height (cm), days to first flowering, number of pods per plant, number of seeds per pod and test weight (1000-seed weight) were taken from randomly selected 10 plants from each plot. Biological yield (g/m^2) and grain yield (g/m^2) were computed on unit area basis. Following treatments of foliar spray of commercial fertilizer K_2SO_4 in combination with calcium ammonium nitrate (CAN) were applied 40 days and 60 days after sowing:

T_1 = Control
T_2 = 0.5% K_2SO_4 + 1% CAN
T_3 = 0.5% K_2SO_4+ 2% CAN
T_4 = 0.5% K_2SO_4+ 3% CAN
T_5 = 1.0% K_2SO_4+ 1% CAN
T_6 = 1.0% K_2SO_4+ 2% CAN
T_7 = 1.0% K_2SO_4+ 3% CAN
T_8 = 1.5% K_2SO_4+ 1% CAN
T_9 = 1.5% K_2SO_4+ 2% CAN
T_{10} = 1.5% K_2SO_4+ 3% CAN

The data so collected were analyzed using Statistix Software 8.1.1.0 and treatment means were compared by least significant difference (LSD) test (α=0.05).

RESULTS AND DISCUSSION

The results indicated that plant height was significantly increased by exogenous application of 3% CAN in combination with 1% or 1.5% SOP under terminal drought stress (Fig. 1). Least plant height was observed for the plants not receiving exogenous nutrients. The plots which did not receive foliar nutrition of CAN and SOP were early to flower while more number of days was taken for flowering with foliar nutrition. The maximum delay in flowering was witnessed in T_7 (3% CAN + 1.0% SOP) followed by T_{10} (3% CAN + 1.5% SOP) (Fig. 2).

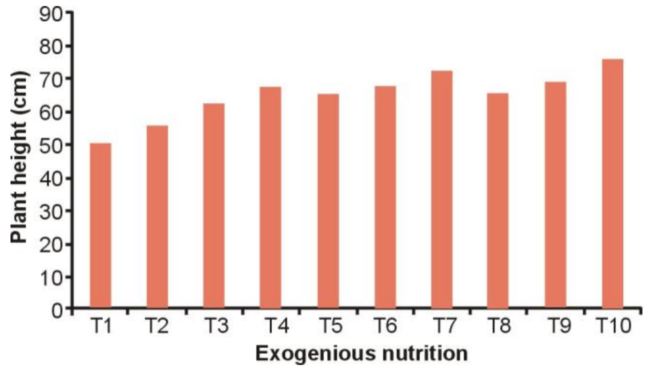

Fig. 1. Effect of exogenous nutrition of CAN and SOP on plant height (cm) of chickpea subjected to terminal drought stress

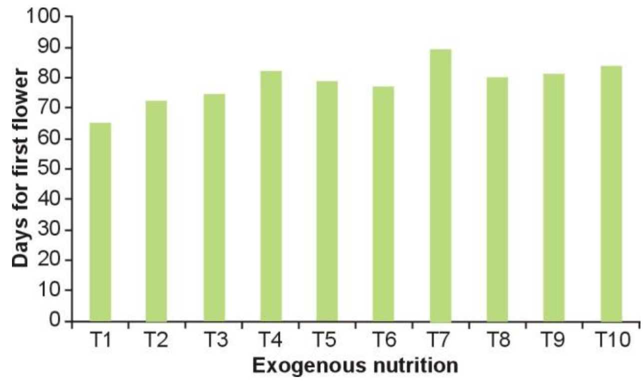

Fig. 2. Effect of exogenous nutrition of CAN and SOP on number of days taken for first flower by chickpea subjected to terminal drought stress.

Terminal drought stress significantly reduced number of pods per plant (Fig. 3), number of grains per pod (Fig. 4), 1000-seed weight (Fig. 5), grain yield (Fig. 6) and biological yield (Fig. 7) in plots which did not receive foliar nutrition. However, number of pods per plant, biological yield (g/m^2) and grain yield (g/m^2) were significantly increased by foliar application of CAN and SOP. Pods per plant (Fig. 3), 1000-seed weight (Fig. 5), grain yield (Fig. 6) and biological yield (Fig. 7) were the highest in T_9 and T_{10} i.e. combined application of 1.5% SOP with 2% or 3% CAN, while these parameter were significantly lower for check plots which did not receive foliar nutrition and faced terminal drought stress. Similarly, foliar application and 3% CAN+1% or 1.5% SOP) yielded significantly higher number of grains per pod against control plots (Fig. 4).

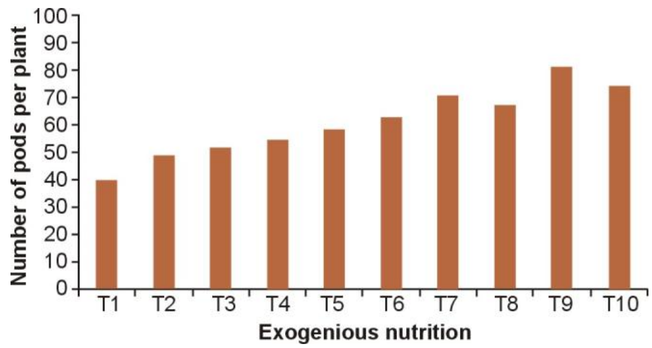

Fig. 3. Effect of exogenous nutrition of CAN and SOP on number of pods per plant of chickpea subjected to terminal drought stress.

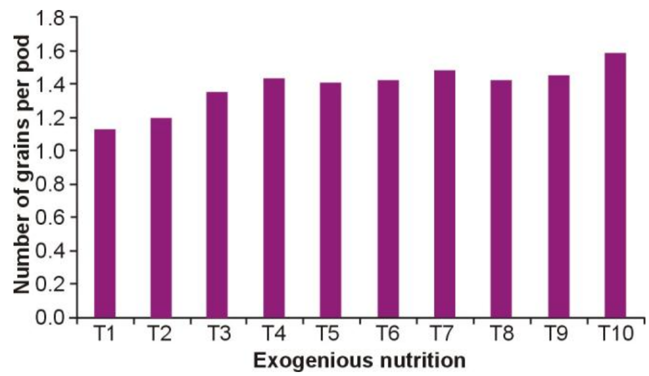

Fig. 4. Effect of exogenous nutrition of CAN and SOP on number of grains per pod of chickpea subjected to terminal drought stress.

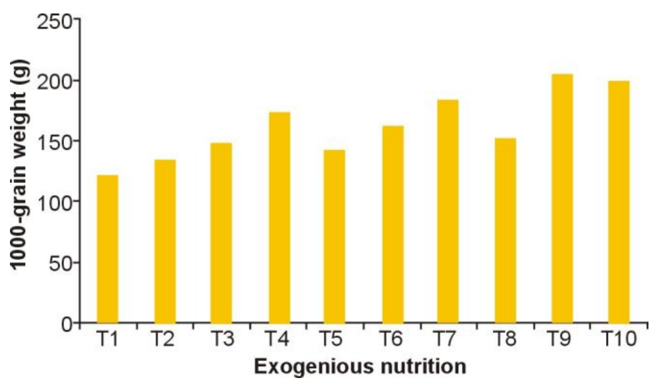

Fig. 5. Effect of exogenous nutrition of CAN and SOP on 1000-grains weight of chickpea subjected to terminal drought stress.

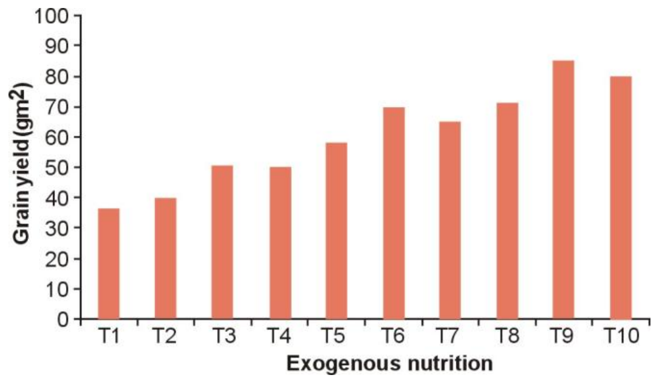

Fig. 6. Effect of exogenous nutrition of CAN and SOP on grain yield (g/m^2) of chickpea subjected to terminal drought stress.

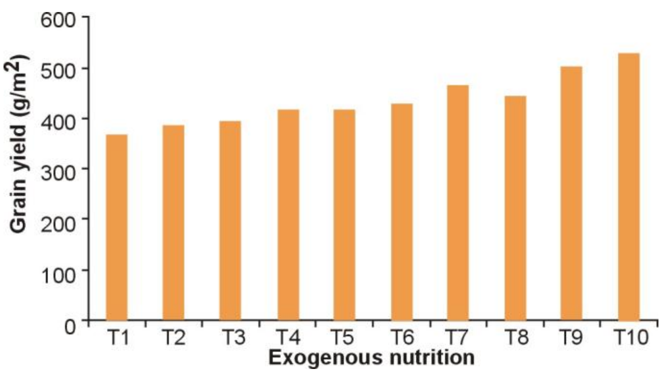

Fig. 7. Effect of exogenous nutrition of CAN and SOP on biological yield (g/m^2) of chickpea subjected to terminal drought stress.

Cell expansion and cell growth is greatly suppressed by water stress due to low turgor pressure, resulting in reduced plant height. Therefore, stem length of pulses is significantly decreased under water deficit conditions (17). However, osmotic regulation brought about by accumulation of organic and inorganic osmoticum supplied whether from the roots or exogenously through foliage assists plant growth and enables the plants to survive under drought conditions. Consequently, optimum plant height contributes to higher number of pods bearing branches and produces more number of pods per plant in addition to seed yield and dry matter (16). Poor management strategies under water stress conditions reduces seed yield in pulses commonly as a result of fewer number of pods and seeds per unit area (17). Foliar application of N before onset of terminal drought produced 20 percent more biomass at maturity in chickpea, supporting that growth prior to the development of moisture deficit stress increased the carbon sources for sustained seed-filling under situation of terminal drought stress (22). Under ample supply of moisture, nitrogen is translocated from leaves to the developing seeds. Any limitation in nitrogen translocation due to moisture stress during seed filling results in swift decline in photosynthesis, thus limiting productivity of legumes (24). The increased 1000-seed weight (Fig. 5) from foliar application of CAN and SOP may probably result from better translocation of photosynthates and osmotic adjustment. Similarly, Bardhan *et al* (6) is of the opinion that in legumes, plant growth besides nitrogen fixation is adversely affected by moisture stress. Accordingly, exogenous nitrogen nutrition may appear to mitigate water stress and can increase drought tolerance. Earlier, significant increase in plant height, total biomass, dry weight, test weight and grain yield under non-irrigated conditions from foliar application of KNO_3 (200 ppm) at 40 and 60 days after sowing is also reported (6).

The plant tissue concentration of K^+ is increased with foliar application of potassium which acts as osmoticum and improves drought tolerance of plants. For example, significant increase in pod yield of groundnut from foliar and soil applied KCl and K_2SO_4 used @ 0.5 and 1.0% with no leaf burn is reported (26). Similarly, Sarkar and Malik (23) had reported that foliar spray of $Ca(NO_3)_2$ and KNO_3 exerts conspicuous effects on yield attributes of grain legumes and improvements in the yield and yield components was attributed to accelerated availability of N in the plant system, greater chlorophyll synthesis, more accumulation of protein and efficient translocation of assimilates to reproductive parts.

It is notable that the plants which did not receive foliar nutrition (control) were early to flower (drought escape, which casts yield reduction), while flowering was delayed in plots which received 1.5% K_2SO_4 in combination with 2% or 3% CAN (Fig. 2). Fictional stay green for longer time and delay in flowering under drought stress conditions results in yield increment. Contrary, less number of days for vegetative growth results in less build up of assimilates for reproductive growth stages and consequently confers low dry matter production and grain yield. Since, chickpea is a long day plant and any delay in flowering would facilitate more dry matter production, and foliar nutrition had been reported promising for more dry matter production than control (6).
Besides ammonical and nitrate nitrogen, CAN also provides Ca^{2+} and sulphur. Similarly, SOP is also a source of sulphur. The exogenous Ca^{2+} enhances drought tolerance of plants and also modifies phenological events

of crops, particularly reproductive maturity is significantly delayed (18). Ca^{2+} also plays pivotal role in improving water holding capacity of leaves or increasing water use efficiency and improves root-to-shoot ratios. Grain yield per unit area and grain weight is significantly increased by exogenous application of Ca^{2+} (18). Similarly, sulphur nutrition has significant effect on nitrogen fixing capacity of legumes.

Another defined benefit of foliar nutrition comes from what is known as "photon pump priming effect" mechanism. By this mechanism, chlorophyll synthesis is increased and this extra synthesized chlorophyll results in an increase in cellular activity and respiration that increases uptake capacity of the plant vascular system in response to the increased water needs of the plant. This increased uptake capacity automatically brings more nutritional elements into the plant system resulting in production of excess sugars. These synthesized sugars are excreted by the root hairs which in turn stimulate microbial activities on the roots by providing additional energy sources. The microbes in turn provide root stimulation compounds, auxins and mineral nutrients to the plants. Consequently, more root tissue and root hairs further increase the plant's ability to uptake water and mineral elements and help to augment drought stress. Great efficiencies can be obtained with foliar nutrition when we stimulate this pumping mechanism (21).

CONCLUSION

The yield potential of chickpea grown in semi-arid tropics under conserved soil moisture systems facing terminal drought stress can be increased by exogenous application of 1.5% K_2SO_4 in combination with 2% or 3% CAN,40 days and 60 days after sowing.

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Received: July 27, 2015 Accepted: April 27, 2016

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Abdul Razzaq	**:**	**Supervised the research**
Abdul Qayyum	**:**	**Helped in writeup**
Ahmad Ali Khan	**:**	**Helped in data analysis**