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THE IMPACTS OF NANO-STRUCTURED NUTRIENTS ON CHICKPEA PERFORMANCE UNDER SUPPLEMENTAL IRRIGATION

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Abstract

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Chickpea is a legume of the family *Fabaceae* and the most widely grown crop in the semi-arid Mediterranean regions. This pulse crop can grow on almost any soil and is well adapted to the semi-arid conditions, but for good growth it requires a fertile soil with good residual moisture. Therefore, nutrient-and water-management practices are necessary agronomic options to improve chickpea production. The objective of this study was to evaluate the effect of different conventional and nano-fertilizers on growth and yield of Kabuli chickpea under supplemental irrigation. The experiment was carried out at a research field in dry highland of Maragheh, North western Iran. Plants were grown under rainfed situation during the vegetative growth and supplement irrigations was applied during flowering and seed filling stages. The effect of nine nutrient treatments including T_1: control (no fertilizer application), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: organic manganese, T_7: conventional NPK fertilizer, T_8: multi-nutrient nano-fertilizer and T_9: nano-chelated zinc were evaluated. Result showed that application of multi-nutrient nano-fertilizer, conventional NPK fertilizer and nano-chelated Zn considerably improved the both vegetative growth (e.g. plant height, canopy width, number of the branches) and yield components. Also the highest chlorophyll concentration ($P < 0.05$) was recorded for plant grown by application of multi-nutrient/compound fertilizers. There was a significant positive correlation between chlorophyll concentration and seed yield components ($P < 0.01$). Among the applied micronutrients, plants significantly responded to nano-chelated Zn. Conventional NPK significantly improved the lateral growth (canopy width, ground cover, branches numbers).The results pointed out that the best performance of chickpea could be achievable through utilization of nano- of multi-nutrient fertilizer, with the simultaneous release of micronutrients and macronutrients. The findings provided illustrative information in order to appreciate the importance of balanced crop nutrition in semi-arid Mediterranean region.

Keywords: balanced nutrition, growth characteristics, multi-nutrient fertilizer, nano-sized particles, yield components

INTRODUCTION

Pulses are the edible seeds of plants in the legume family and are important source for balanced human diet throughout the word. Pulses have a wide range of adaptability to latitudes, longitudes and climatic variables. Among the Pulses, chickpea (*Cicer arietinum* L.) is the third leading grain legume in the word and is one of the most important cool-season crop in the semi-arid regions like as Turkey, Iran, and India (Yadav *et al.*, 2007). The total harvested area of chickpea in word is 13.98 million ha and it covers 16.4 % of the total cultivated area and contributes to 17 % (13.3 million ton) of the world's pulse harvest of about 78 million tons (FAO, 2013). Furthermore, chickpea is vital part of the crop rotations in west of Iran and is a major source of dietary protein. However, chickpea production on the semi-arid Mediterranean regions is faced with numerous problems such as low soil fertility, short growing season, terminal high temperature, low and variable precipitation. Chickpea plays an important role in improving the diet quality in developing country. The request of pulses is fast increasing to meet the minimum protein requirements of an increasing world population (Sardana *et al*., 2010). Hence, it needs special attention and efficient managements, otherwise it can bring a serious challenge on the food security, particularly in the developing countries.

In the west of Iran, which has moderately cold wet winters and hot dry summers (June–August), chickpea is conservatively sown in spring (March–April), which approximately corresponds with the end of the rainy season in this region (Oweis *et al*., 2004). Thus, spring-sown chickpea growth is largely restricted by terminal drought. In this context, Zaman-Allah *et al.* (2011) and Leport *et al.* (2006) reported that terminal drought stress can reduce seed yields by as much as 58–95 % when compared with full irrigated situation. However production of chickpea under rainfed condition is very dependent on rainfall that is generally scarce and very variable and on residual soil moisture. On the other hand full irrigation of this crop due to limited water resources and high net irrigation requirement of other spring crops, is not entirely possible.

It appears that restricted water supply during the mid-season or terminal dry spells can, however, play a critical role in enhancing and stabilizing the productivity of spring-sown chickpea. It has been revealed that supplemental irrigation, generally applied between flowering and the beginning of seed growth, can improve significantly spring-sown chickpea yield (Oweis *et al*., 2004, Silva *et al*., 2014). The effect of different irrigations and sowing date on yield and water use efficiency has been investigated in some studies (Zaman-Allah *et al*., 2011; Pasandi *et al*., 2014; Silva *et al*., 2014). Although water availability can be a major restrictive factor for chickpea production systems in semi-arid regions, there are other factors, such as low soil fertility and nutrients deficiency that can have a significant negative effect on chickpea production (Yadav *et al*., 2007).

However, there is little information about the effects of fertilizers managements under supplemental irrigation on growth and yield components of chickpea in semi-arid Mediterranean regions. Soil fertility refers to a capability to supply essential plant nutrients and soil water in adequate amounts and proportions for plant growth and reproduction which promote and support long term sustainable productivity of the soil (Havlin *et al*., 2005). In the Mediterranean semi-arid regions low fertility is of great concern, since the soils of these area are deficient in major and essential elements such as nitrogen (N) and phosphorus (P) and several micronutrients (Ryan, 2010). This is partly due to (i) intensive crop cultivation using high yield varieties of crop with imbalanced fertilization coupled with high nutrient turn over in soil-plant system, (ii) deficiencies of micro and secondary nutrients, (iii) wide nutrient gap between nutrient demand and supply, and (iv) low fertilizer use efficiency (Rao and Reddy, 2010). Consequently, nutrient deficiencies or nutrient imbalance has been reported for a long period of time in these region.

However, sustainable nutrient use efficiency could be attained by agronomic mangments which take into account timely synchronization of nutrient application with plant roots development, or use of slow-release fertilizers, and foliar feeding (Oosterhuis and Howard, 2008; Selva-Preetha *et al*., 2014). During the last decade, some studies tried to examine the potential of nano-biotechnology to improve nutrients use efficiency and strategies that result in the design and development of efficient new nano-fertilizer delivery platforms for use at the farm level (Naderi and Danesh-Shahraki, 2013; Rameshaiah and Jpallavi, 2015). Nano-formulated fertilizers presents unique physico-chemical properties, so that they can fulfil plant root requirements more efficiently in comparison with conventional fertilizers (in the form of salts or in bulk size). The gradual and regulated release of the nutrient could be through the process of dissolution and ion exchange reactions (Mukhopadhyay, 2014). Utilization of nano-fertilizers may increase solubility and dispersion of insoluble nutrients in soil, reduce nutrient immobilization (soil fixation) and increase their bio-availability (Naderi and Danesh-Shahraki, 2013). However, it is important to note that the availability of soil water to plants may significantly affect nutrients uptake and the rate of water movement in the soil-plant-atmosphere system. Thus, the soil solution concentration and plant transpiration rate determine the quantity of ions transport (Oliveira *et al*., 2010). Although there is a few information about the nano-fertilizers, they are mostly related to well-watered conditions. Therefore, the present study aimed to investigate the effect of different nano-fertilizers on the development and yield of spring-sown chickpea under supplemental irrigation in North West of Iran.

MATERIALS AND METHODS

This experiment was carried out in the research field of the Department of Agronomy and Plant Breeding, University of Maragheh, East Azarbaijan, Iran, during the year 2015–2016. The field was located at 46°16′ East longitude and 37°23′ North latitude, at an altitude of 1485 meter from sea level. Maragheh is representative of highland semi-arid zone and according to updated classification of Köppen and Geiger its climate is classified as BSk; cold semi-arid climate (PEEL *et al.*

I: *Precipitation, mean humidity and mean temperature in crop seasons of 2016 at Maragheh station.*

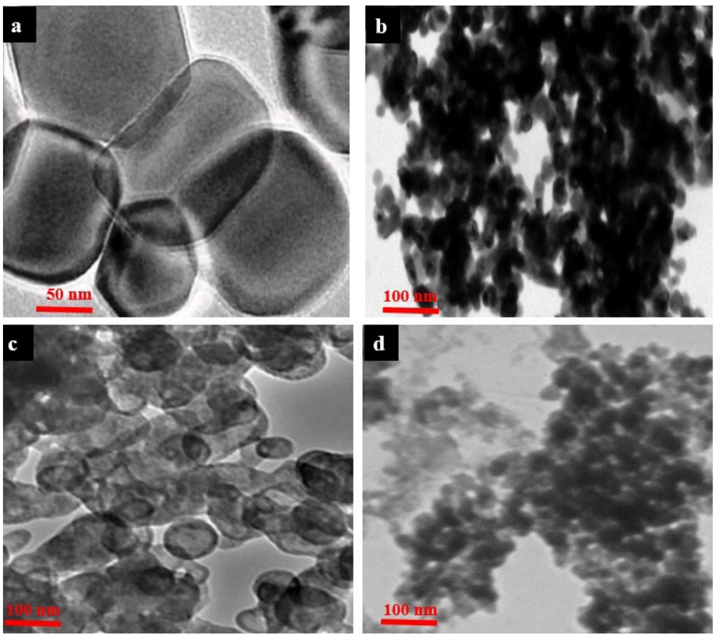
Climatic parameters	March	April	May	June	July
precipitation (mm)	43	51	2057	25.9	13
Mean humidity (%)	57	50.2	40.1	31.7	30.8
Total evaporation (mm)	14	32	49	193	278
Mean Temperature (°C)	8.5	13.7	19.2	23.9	26.3

2007) with an average annual precipitation of 353 mm. This district is large elevated area and is located in the mountainous site of Sahand Mountain in northwestern Iran. Rainfall is not generally well-distributed through the year and the occurrence of rainfall during late winter and early spring is frequent, with about ten days per month on average. However, rainfall from June to October is low, when the highest rate of evapotranspiration occurs. Application of the irrigation is required in that period. Tab. I shows the monthly meteorological data during the growth season. The soil texture of the experimental site is sandy loam, comprising of 53 % sand, 31 % silt and 16 % clay. It contains 0.14 % organic matter (OM) with a pH of 7.87. The soil texture is 53 % sand, 31 % silt, and 16 % clay, with electrical conductivity (EC) = 1.96 ds m^{-1}, 0.058 % nitrogen (N), 5.67 available phosphorus (mg kg^{-1}), and 342 mg kg^{-1} available potassium (K).

The previous crop was safflower (*Carthamus tinctorius* L.). After deep ploughing at autumn of 2015 the field was abandoned as bare fallow during the winter. Soil disked tow times before the planting and seeds were hand planted on 2 April, 2016. The Kabuli Chickpea (*Cicer arietinum* L.) cultivar "Arman" was used in the experiment. The experiment was laid out according to randomized complete block design (RCBD) with three replications and a net plot size as 4 × 3 m. Each plot included twenty rows, 4 m long and 25 cm apart. Seeds were sown 8 cm apart at 10 cm depth. The small terraces of 1.5 m in the interspaces was considered to prevent contamination by surface run-off containing fertilizer.

There was no incidence of pest or disease on plants during the experiment. Weeds were controlled over the growth period with hand hoeing. At field capacity and at the permanent wilting point, mean soil moisture content in the top 50 cm of the soil is about 34 and 12 % by weight, respectively. Plants were grown under rainfed condition with two supplemental irrigations during the reproductive stage (flowering and seed filling stages). The amount of irrigation water was calculated to restore water content in the root zone to field capacity. Depth of net irrigation water fraction was ~110 mm. All other necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation.

The treatments comprised of T_1: control (no fertilizer application), T_2: nano-chelated iron (produced by nano-particles of Fe_3O_4), T_3: nano-chelated manganese (contained nano-particles of manganese oxide),



1: *Fig. 1. Transmission electron microscopy (TEM) micrograph of boric acid (H_3BO_3) (a), copper (II) oxide (b), ferric oxide (c), and manganese oxide (d) nanoparticles utilized for production of nano-fertilizers.*

T_4: nano-chelated copper (synthesized by nano-particles of copper (II) oxide), T_5: nano-chelated boron which contained nano-particles of boric acid (H_3BO_3), T_6: organic manganese (Organic BioLink® Manganese fertilizer; 6 % Mn), T_7: NPK fertilizer, T_8: nano cchelated multi-nutrient fertilizer and T_9: nano-chelated zinc (synthesized by nano-particles of ZnO). Multi-nutrient nano-fertilizer contained 11 essential elements (N = 5 %, P = 3 %, K = 3 %, Fe = 4.5 %, Zn = 8 %, Ca = 6 %, Mg = 6 %, Mn = 0.7 %, Cu = 0.65 %, B = 0.1 %, Mo = 0.65 %). Nano-chelated fertilizers were obtained from the Unikeyterra Chemical Agriculture Company (Turkey) and Sepehr Parmis Company, Iran. Synthesized nano-particles had been characterized morphologically by a transmission electron microscope (Fig. 1). Conventional NPK (20:20:20) fertilizer applied at rate of 120 kg ha^{-1}in two split application i.e. half as pre-plant (starter fertilizer) and half as post-emergence side dress application during early bloom stage. Nano-chelated micronutrients (Fe, Mn, Cu, Zn, B) and multi-nutrient nano-fertilizer applied at soil before the planting (1 kg ha^{-1}) and also utilized on foliage during the early bloom (R_1) and seed filling (R_4) stages (2,000 ppm).

Groundcover was determined as amount of plant material (dead or alive) that covers the soil surface. It was expressed as a percentage through visual assessment; 100 % groundcover means that the soil cannot be seen and 0 % groundcover is bare soil. The average canopy width is the average horizontal width of the plant canopy, taken from right to left as one moves around the plant. Groundcover and canopy spread was measured during the seed filling stage. Chlorophyll index was measured on ten leaves of a plant at each plot, using a portable chlorophyll meter (SPAD-502; Minolta, Japan) at grain filling stage (R_4). Chlorophyll was measured in fully expanded upper leaves. The plants were harvested at maturity on 20 August and yield components were recorded. At maturity stage data were recorded on random sample of 10 plants from each plot for plant height [cm], length of pod bearing branch [cm], primary branches and secondary branches per plant, pods per plant, seeds per pod, 100 seed weight [g], biological yield [kg/ha] and seed yield per plant [kg/ha]. Harvest Index was determined as the ratio of grain yield to biological yield. Number of days to maturity was calculated from the date of sowing to the harvesting date of the crop. Number of primary branches was recorded as the branches sprouting from the main stem. Number of secondary branches was counted as the branches originating from the main stem which are directly pod bearing branches. Plant height was determined in centimeters from soil surface to the top of the main branch. The data on number of pods per plant was calculated as total number of pods recorded at maturity. After harvest, biological yield of each treatment was recorded in grams as total dry weight at maturity. Grain yield per plant was recorded in grams after threshing. Number of seeds per plant was counted and was divided by number of pods to get the data of number of seeds per pod. 100-seed weight was measured on two 100 seed assessments and recorded in grams. All data were subjected to an analysis of variance (ANOVA) for each character. The statistical analysis of experimental data utilized the SAS program was used to statistical analysis. The least significant difference (LSD) at 5 % was used to compare between means. Pair-wise Pearson's correlation coefficient was calculated between traits.

RESULTS

Variance analysis showed that the effect of the nutrient on day to 50 % flowering was statistically

II: *Effect of different fertilizers treatments on morpho-physiological traits of chickpea (Cicer arietinum L.) plants under supplemental irrigation.*

Treatment	DF	CW	GC	PH	PB	SB	DOF	FPH
Control (No fertilizer)	70.66^{ab}	27.33^{d}	66.66^{ef}	30.00^{d}	2.64^{d}	2.66^{c}	28.00^{a}	12.83^{bc}
nano-chelated iron	70.00^{ab}	30.66^{c}	73.00^{dc}	33.66^{bc}	2.86^{bc}	3.40^{ab}	28.66^{a}	13.60^{b}
nano-chelated manganese	67.33^{abc}	31.00^{c}	66.00^{f}	29.66^{d}	2.50^{cd}	3.06^{bc}	30.50^{a}	13.13^{b}
nano-chelated copper	71.66^{a}	33.33^{bc}	66.00^{f}	31.33^{cd}	2.46^{d}	2.76^{c}	33.00^{a}	12.76^{bc}
nano-chelated boron	72.00^{a}	30.66^{c}	72.33^{de}	33.66^{bc}	2.43^{d}	2.56^{c}	31.33^{a}	13.13^{b}
organic manganese	67.00^{bc}	31.00^{c}	69.66^{def}	30.00^{d}	2.33^{d}	2.70^{c}	36.00^{a}	12.81^{bc}
NPK bulk fertilizer	64.33^{cd}	39.00^{a}	84.66^{a}	38.33^{a}	3.16^{ab}	3.76^{a}	40.50^{a}	15.46^{a}
Nano multi-nutrient	64.5^{cd}	36.33^{ab}	78.33^{bc}	35.00^{b}	3.33^{a}	3.43^{ab}	38.00^{a}	15.56^{a}
nano-chelated zinc	60.66^{d}	37.66^{a}	83.00^{a}	39.00^{a}	3.10^{ab}	3.70^{a}	41.33^{a}	16.10^{a}
LSD	4.64	3.21	5.87	3.17	0.39	0.57	14.76	0.99
Level of significance	*	**	**	*	*	**	NS	*

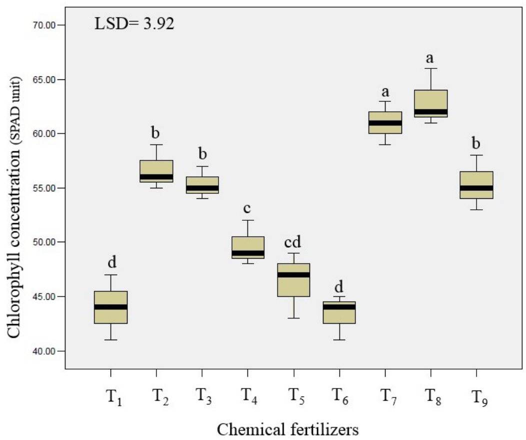
DF: number of day from sowing to 50 % of flowering, CW: canopy width (cm), GC: ground cover percentage by canopy, PH: plant height (cm), PB: number of primary branches, SB: number of secondary branches, DOF: Duration of flowering (day), FBH: height of the first pod (cm). LSD: Least Significant Difference at P ≤ 0.05. In each column, values with similar letter(s) are not significantly different at the 5 % level of probability. NS = Not significant, * = Significant at 5 % level of probability, ** = Significant at 1 % level of probability.

significantly ($p < 0.05$). Mean comparison revealed that plants grown by application of nano-chelated zinc initiated the flowering stage earlier than others (Tab. II). However the assessment of the flowering duration indicated the nutrition treatment could not affect this parameter. The evaluation of canopy width clearly showed that the application of nutrient significantly induce the canopy growth ($p < 0.01$). So that the smallest canopy width was recorded for control condition (no fertilizer application) and the widest canopy was recorded for plants grown by NPK bulk fertilizer and nano-chelated zinc. Utilization of the NPK fertilizer increased the canopy width up to 42 % over the control (Tab. II). A comparable trend was observed in ground cover percentage. The highest ground cover was obtained by application of NPK bulk fertilizer, nano-cheated zinc and multi-nutrient nano-fertilizers, respectively.

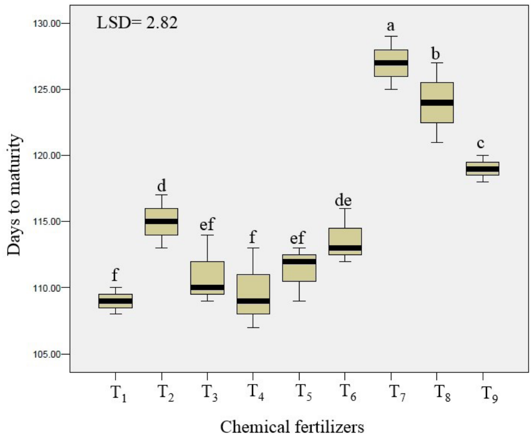
Plant height influenced by nutrient application with a 95 percent confidence interval (Tab. II). The longest plant recorded under application of nano-chelated zinc and NPK bulk fertilizer, while the shortest plant was related to nano-chelated manganese and control condition. Utilization of zinc fertilizer increased the plant height up to 30 % over the control. The number of the both primary and secondary branches significantly influenced by nutrients treatments. Application of nano-chelated manganese, nano-chelated copper, organic manganese and nano-chelated boron could not improve these traits in comparison with control. However, consumption of NPK bulk fertilizer, multi-nutrient nano-fertilizer and nano-chelated zinc noticeably increased the number of the branches.

The first pod height is an important trait for mechanical harvest. Our results revealed that this trait significantly affected by application of different fertilizers ($p < 0.05$). The lowest height of first pod was recorded for nano-chelated copper, organic manganese and control condition (Tab. II). While the application of nano-chelated zinc, nano-multi-nutrient and NPK bulk fertilizer considerably raised the positions of the first pod formation. Chlorophyll concentration noticeably affected by nutrients application and the highest value was recorded for plants grown by nano-multi-nutrient and bulk NPK fertilizer and was followed by nano-chelated iron, nano-chelated zinc and nano-chelated manganese (Fig. 2). On average, application of nano-multi-nutrient and NPK fertilizers increased the chlorophyll concentration up to 43 % and 38 % over the control, respectively. Furthermore, evaluation of the days to maturity showed that utilization of NPK and multi-nutrient nano-fertilizers significantly increased the duration of both vegetative and reproductive stages and delayed the maturity (Fig. 3). In this context, there was found a significant correlation between number of the days to maturity and seed yield ($r^{**} = 0.96$). These results may reflects the improvement of the leaf area duration by application of the both modern and conventional multi-nutrient fertilizers.

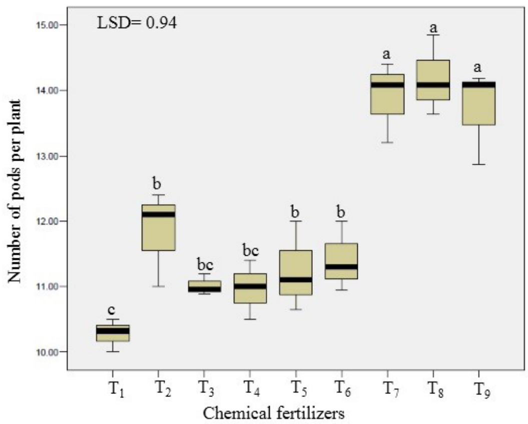
Nutrient treatments significantly affected the length of pod bearing branches ($p < 0.05$). Although the fertilizers application increased the length of pod bearing branches over the control, there was no significant difference between treatments, except to nano-chelated iron. Evaluation of straw yield revealed that the highest vegetative growth achieved by application of NPK and multi-nutrient nano-fertilizers. So that these fertilizers respectively increased the straw yield up to 45 % and 37 % over the control. Pod weight per plant noticeably ($p < 0.05$) affected by application of NPK, multi-nutrient and nano-chelated zinc fertilizer (Tab. III). Utilization of conventional macronutrients (NPK) increased the pod weight up to 36 % over the control. A similar trend observed for pod number per plant (Fig. 4). Except nano-chelated



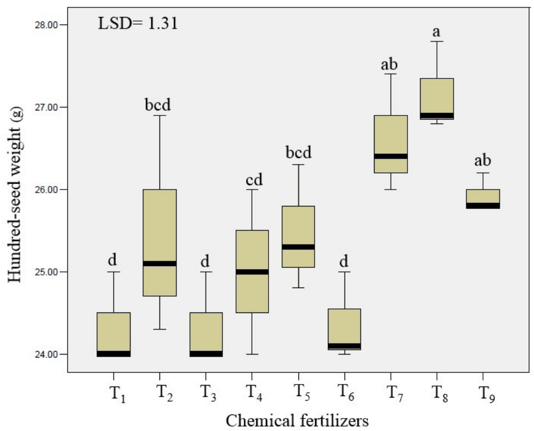
2: *The influence of bulk and nano-fertilizers on chlorophyll concentration of chickpea leaves under supplemental irrigation*
T_1: control (no fertilizer application), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: organic manganese, T_7: NPK bulk fertilizer, T_8: multi-nutrient nano-fertilizer and T_9: nano-chelated zinc.



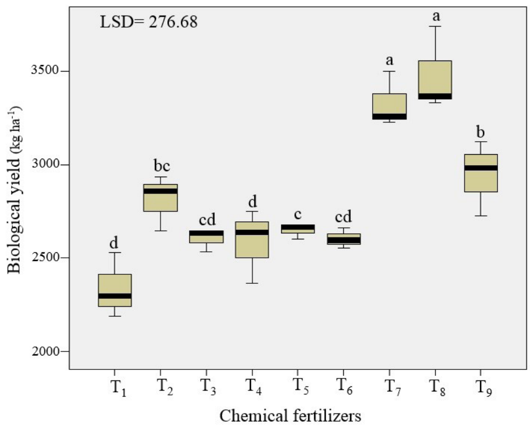
3: *The effect of macro and micro nutrients application on days to maturity of Kabuli chickpea, as an important phenelogical trait, in semi-arid region*
T_1: control (no fertilizer application), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: organic manganese, T_7: conventional NPK fertilizer, T_8: multi-nutrient nano-fertilizer and T_9: nano-chelated zinc.



4: *Number of the pod in chickpea plants affected by application of different fertilizer*
T_1: control (no fertilizer application), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: organic manganese, T_7: NPK bulk fertilizer, T_8: multi-nutrient nano fertilizer and T_9: nano-chelated zinc.



5: *Impact of nano and bulk chemical fertilizers on 100-seed weight of Kabuli chickpea in semi-arid region*
T_1: control (no fertilizer application), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: organic manganese, T_7: NPK bulk fertilizer, T_8: multi-nutrient nano fertilizer and T_9: nano-chelated zinc



6: *Biological yield of Kabuli chickpea affected by application of micro or macro-nutrients in semi-arid region with supplemental irrigation*
T_1: control (*no fertilizer application*), T_2: nano-chelated iron, T_3: nano-chelated manganese, T_4: nano-chelated copper, T_5: nano-chelated boron, T_6: *organic manganese*, T_7: NPK bulk fertilizer, T_8: multi-nutrient nano-fertilizer and T_9: nano-chelated zinc.

copper and nano-chelated manganese, the rest of fertilizers considerably increased the number of pods per plant compared to the control condition. However, the number of the unfilled pod per plant also influenced by fertilizer treatments, so that the highest number of unfilled was recorded for plant grown by nano-chelated zinc and NPK fertilizers, whereas the lowest unfilled pod was obtained by application multi-nutrient nano-fertilizer (Tab. III). Mean comparison for 100-seed weight showed that the heaviest seed obtained by application of by NPK and multi-nutrient nano-fertilizers (Fig. 5). A parallel trend also was observable for harvest index (Tab. III). Superiority of the mentioned treatments (T_7, T_8, T_9, and T_2) also was apparent in biological yield (Fig. 6).

The correlations between different traits are presented in Tab. IV. Seed yield was observed to be significantly and positively correlated at 1 % significance level with days to maturity, number of the primary branches, pod weight, height of the first pod and 100-seed weight. Also a between the seed yield and chlorophyll content, canopy width, ground cover and plant height observed a positive correlation at 5 % significance level. One the most interesting finding was that significant positive correlation of chlorophyll content with most of the yield component, so that it can be introduced as suitable descriptor for evaluation chickpea performance in response to nutrient managers in semi-arid region.

III: *Yield components of chickpea (Cicer arietinum L.) affected by different nutrient management in semi-arid region under supplemental irrigation condition.*

Treatment	PW	LPB	UPN	SP	SY	STY	HI
Control (No fertilizer)	16.17^{b}	12.33c	5.10^{ab}	1.23^{a}	781.33^{e}	1554.34^{c}	33.46^{d}
nano-chelated iron	16.53^{b}	14.06bc	3.63^{bc}	1.32^{a}	979.00^{bc}	1832.69^{b}	34.81^{abc}
nano-chelated manganese	14.58^{b}	14.66abc	3.93^{abc}	1.12^{a}	892.00^{cd}	1708.92^{bc}	34.29^{bcd}
nano-chelated copper	16.16^{b}	15.00ab	4.16^{abc}	1.43^{a}	877.00^{d}	1706.43^{bc}	33.96^{cd}
nano-chelated boron	15.33^{b}	15.16ab	4.16^{abc}	1.50^{a}	912.00^{cd}	1733.10^{bc}	34.46^{bcd}
organic manganese	16.33^{b}	16.25ab	4.60^{abc}	1.32^{a}	884.67^{d}	1718.73^{bc}	33.99^{cd}
NPK bulk fertilizer	22.03^{a}	17.16a	5.36^{a}	1.19^{a}	119.00^{a}	2139.41^{a}	35.73^{a}
Nano multi-nutrient	21.83^{a}	16.16a	3.13^{c}	1.42^{a}	1225.33^{a}	2256.30^{a}	35.20^{a}
nano-chelated zinc	20.16^{a}	17.00a	5.90^{a}	1.13^{a}	1047.33^{b}	1896.67^{b}	35.63^{a}
LSD	2.54	2.58	1.54	0.65	89.34	194.34	1.092
Level of significance	*	*	*	NS	**	**	*

IV: *Pearson's correlation coefficients among agronomic and morpho-physiological traits of chickpea (Cicer arietinum L.).*

	DF	CC	CW	GC	PH	DM	PB	SB	LPB	PW	FBH	NPP	UP	HSW	SY	STY	BY
CC	–0.58																
CW	–0.77	0.73															
GC	–0.77	0.65	0.85														
PH	–0.68	0.63	0.85	0.96													
DM	–0.74	0.79	0.86	0.91	0.80												
PB	–0.72	0.89	0.80	0.86	0.82	0.90											
SB	–0.78	0.87	0.81	0.84	0.82	0.84	0.90										
LPB	–0.75	0.52	0.88	0.76	0.69	0.77	0.59	0.59									
PW	–0.75	0.71	0.87	0.89	0.81	0.94	0.91	0.79	0.71								
FBH	–0.86	0.80	0.92	0.93	0.90	0.89	0.91	0.89	0.82	0.88							
NPP	–0.83	0.80	0.91	0.93	0.87	0.95	0.94	0.86	0.83	0.94	0.97						
UP	0.14	–0.40	–0.09	0.00	–0.06	–0.04	–0.30	–0.17	–0.14	–0.02	–0.29	–0.25					
HSW	–0.54	0.79	0.80	0.84	0.82	0.88	0.91	0.71	0.67	0.88	0.86	0.91	–0.30				
SY	–0.69	0.87	0.86	0.86	0.79	0.96	0.93	0.82	0.77	0.91	0.91	0.96	–0.26	0.95			
STY	–0.64	0.86	0.83	0.80	0.72	0.95	0.91	0.77	0.74	0.90	0.86	0.94	–0.29	0.94	0.99		
BY	–0.66	0.87	0.84	0.83	0.75	0.96	0.92	0.79	0.75	0.90	0.88	0.95	–0.28	0.95	1.00	1.00	
HI	–0.76	0.81	0.88	0.94	0.94	0.88	0.88	0.91	0.77	0.81	0.96	0.93	–0.21	0.84	0.89	0.83	0.86

Critical values of correlation $P < 0.05$ and $P < 0.01$ are 0.70 and 0.90, respectively. Abbreviation; DF: number of day from sowing to 50 % of flowering, CC: chlorophyll concentration, GC: ground cover percentage by canopy, PH: plant height, DM: days to maturity stage, PB: number of primary branches, SB: number of secondary branches, , LPB: Length of pod bearing branches), PW: pod weight per plant, FBH: height of the first pod, NPP: number of pod per plant, UP: number of the unfilled pod per plant, HSW: 100-seed weight, SY: seed yield, STY: straw yield, BY: biological yield, HI: harvest index.

DISCUSSION

Our result revealed that chickpea plant in semi-arid highland area of Maragheh, significantly response to different fertilizers. In current experiment response to all applied nutrient may be resulted from the low soil fertility and severe nutrient deficiencies in this area. Response of chickpea to both macro and micronutrients was evident. Although chickpea is an excellent nodulator and nitrogen fixer, its nodulation is greatly influenced by physicochemical and biological conditions of the soil. With regards to attendance of different limiting factors (e.g., salinity, unfavorable soil pH, nutrient deficiency, temperature extremes, insufficient soil moisture, inadequate photosynthesis, plant diseases, and grazing) in semi-arid region, application of nitrogen fertilizer should be specifically considered for chickpea. It has been revealed that even where the soil or the seed is treated with Rhizobium biofertilizer, an N application is essential. This serves as a starter dose and meets the N needs of the crop until the N-fixation system becomes operational (Roy *et al.* 2006).

Results revealed that application of conventional NPK fertilizers could significantly increase lateral growth. This finding is in agreement with findings of Marimuthu and Surendran (2015) which showed application of NPK and micronutrients mixture increased the height and number of branches in black gram plants in sandy loam soils.

Nutrient treatments affected the plant phenology, vegetative traits and yield components. Phenology is concerned with the timing of events. Results revealed that flowering patterns variously affected of by nutrients management. Flowering patterns are defined by the timing, duration, and frequency of flower production. In this context, application nano-chelated zinc considerably accelerated the flowering stage but could not extend this developmental stage. In plants, the timing of flowering is regulated by mechanisms which act to ensure that flower emergence occurs in suitable conditions (Tooke and Battey, 2010). From the results it can be argued that the mechanisms behind flowering partially affected by plant nutrition. Although, early-maturity helps chickpea to avoid terminal heat and drought stress and increases its adaptation especially in rainfed farming system (Upadhyaya *et al.* 2007), it may result in incomplete seed filling and lower yield under optimum moisture conditions. With regards to application of the supplemental irrigation, extension of the seed filling period resulted in the heavier seeds.

Between the evaluated vegetative traits canopy width, ground cover percentage, number of the branches prominently improved by nano-multi-nutrient, NPK and nano-zinc fertilizers. Importance of ground cover percentage in semi-arid region can be due to shading on the soil surface, reduce the proportion of evaporation from the soil and improvement of water use efficiency. Conservation of soil moisture is essential to mitigate drought and mid-season dry spells.

Among the seed yield components, pod number per plant significantly responded to fertilizers treatments. The highest pod number was recorded for plants grown by application of multi-nutrient/compound fertilize. This finding supports previous research into this brain area which showed that among the yield components pod number per plant considerably responded to improvement of soil fertility by combined nutrients application (Quddus *et al.* 2012).

Although the all fertilizers could increase the seed yield, the highest yield was recorded for plants grown by NPK and multi-nutrient nano-fertilizers and was followed by nano-chelated zinc and Iron fertilizers. The present findings seem to be consistent with other research which found chickpea significantly responded to micronutrient applications in relatively dry soils with low native fertility (Mustafa *et al.* 2008; Valenciano *et al.* 2011; Janmohammadi *et al.* 2011). Seed yield was determined by sink-source interactions and it emphasizes the importance of sources and sinks as determinants of growth and as targets for crop improvement. Source activity refers to the plant ability to produce photoassimilates, while sink activity refers to the internal drawdown of these resources (White *et al.* 2016). The result suggested that the increase of sink size (e.g. pod per plant, seed per pod, seed per plant and 100-seed weight) along with the increase in the size (e.g. plant canopy width) or activity of the source (e.g. chlorophyll concentration) could result in improved yield. These results are in agreement with the result of Singh and Kataria (2012), who also observed that nutrient management supported the sufficient rates of nitrogen fixation and N-partitioning to meet the requirement of two active sinks i.e. reproductive parts and the nodules at the same time.

Although the application of nano-chelated zinc and partially utilization of nano-chelated iron improved the growth and seed yield, the best performance was recorded for plant grown by multi-nutrient fertilizers. On the other hand, Chickpea did not respond to B application and the present findings seem to be consistent with result of Valenciano *et al.* (2011) which found that the positive effects of zinc (Zn) and molybdenum (Mo) application on chickpea yield was more prominent than boron (B) fertilizer.

It is well it is recognized that vegetative growth is largely controlled by growth regulators (phytohormones). It seems that plant nutrient management can potentially change the rate and efficiency of plant growth regulators and can be considered as perfect tool for growth control. However, it is important to note that nutrient modification, by either supplying a plant with an excessive or inadequate amount of nutrients, may be a way to induce growth reduction as a stress response. The results of this study emphasize that application of essential nutrients, such as phosphorous (P), nitrogen (N) and potassium (K), are vital for acceptable plant growth and seed production. Given the key role of nitrogen and phosphorus in intracellular processes, their application in the chickpea production system is very important. For instance, N is a critical component of all amino acids, whereas P is a critical component of adenosine triphosphate (ATP). Besides, it has been reported that N fertilizers can directly affect the phytohormones, so that plants fertilized with N had significantly higher level of indole-3-acetic acid (IAA) and gibberellins compared to N-starved plants (Liu *et al.*, 2011; Wiser, 2014).

Our result revealed that fertilizer management can significantly affect the phenological development. So that the longest growth period were recorded for plant grown by conventional NPK fertilizer and followed by multi-nutrient nano-fertilizer and nano-chelated zinc. The time available for chickpea crops to produce adequate vegetative structures and then grain yield is often restricted by heat and drought stress, or competition for use of land by other crops in rotation. To attain acceptable yield, crop duration (phenology) must closely be synchronized with the suitable environmental factors (Soltani *et al.*, 2006). However, the dynamics of chickpea phenology vary with cultivar, photoperiod, temperature, soil water and nutrient status. Changes in development and maturity time may determine the economic yield in chickpea. Namvar and Sharifi (2011) reported that by increasing the nitrogen supplying to chickpea plants days from planting to maturity considerably increased. However, our finding highlighted that the best growth and phonological development can be achieved by integrated application of nutrients. Besides, findings indicated that plants with longer growth period produced higher biological and grain yield compared to plants that had shorter growth period. Gan *et al.* (2009) reported that short growth duration in general, gives low yields as compared to medium and long growth duration and this is due to the fact that longer development period provides full use of available growth resources like water, nutrient and light for plants, which results in high crop yields.

Assessment of correlation coefficient showed that the number of pods per plant was the most influential yield component, and the one most closely correlated with seed yield (0.96) and can be considered as value parameter for appraising of seed yield response to nutrient managements. The present findings seem to be consistent with results of Valenciano *et al.* (2011). Altogether, results indicated that at maturity, plants fertilized with multi-nutrient nano-fertilizer had a greater total dry matter production and seed yield, mainly due to an increment in pod number per plant and seed weight.

In general, interactions between macronutrients and micronutrients in multi nutrients fertilizer significantly stimulate plant growth. However, such stimulation may cause micronutrients deficiency under limited supply of the microelements in soils (Fageria, 2001). The present findings seem to be consistent with conclusion of other research which showed that integrated application of macro and micronutrients significantly increase the micronutrient efficiency (Monreal *et al.*, 2015).

The novelty of this experiment was the comparison of conventional bulk, organic and nano-fertilizers. The finding highlighted that multi-nutrient nano-fertilizer, conventional NPK and nano-chelated Zn have significant effects on growth and yield chickpea. Integrated application of nutrients resulted in more uniform canopy growth and higher ground cover, and considerably improved the seed yield. Regarding cost and efficiency of multi-nutrient nano-fertilizers, they can be assigned as balanced fertilization option for chick production systems in semi-arid regions, where it is grown with or without irrigation. Adequate and balanced application of nano-fertilizer can significantly improve the nutrient use efficiency.

CONCLUSION

Result of current study revealed that both growth characteristics and yield components of chickpea evidently responded to different fertilizers application. The best growth which was determined by the highest height, wide canopy, large number of branches and high biological yield, observed for plants grown by application multi-nutrient nano-fertilizer, NPK bulk fertilizer and nano-chelated zinc. Also the highest seed yield was obtained by application of multi-nutrient nano-fertilizer. Application of NPK bulk fertilizer was more effective than use of individual micronutrients. Between applied micronutrients, the effect of zinc on the growth and performance was more impressive, likely reflecting severe zinc deficiency in soil of this area. The results emphasized that more accurate nutrient managements with considering both macronutrients and trace minerals is very necessary for chickpea production system. The nest goal in nano-compound fertilizer designing should be increase of nutrient-use efficiency and providing all the needs of plants as one multi-nutrient fertilizer with consistent characteristics for semi-arid areas.Clearly, these preliminary findings show the huge potential of chickpea in this semi-dry environment. Overall, the findings showed that the dramatic increases in chickpea production in could be achievable by better nutrition and through modern nano-fertilizers application supplemental irrigation during critical stages.

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