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EFFECT OF MANURE AND FOLIAR APPLICATION OF GROWTH REGULATORS ON LENTIL (*LENS CULINARIS*) PERFORMANCE IN SEMI-ARID HIGHLAND ENVIRONMENT

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Abstract

Janmohammadi M., Nasiri Y., Zandi H., Kor-Abdali M., Sabaghnia N., 2014: Effect of manure and foliar application of growth regulators on lentil (*Lens culinaris*) performance in semi-arid highland environment [Mėšlo ir augimo reguliatorių poveikis lęšių (*Lens culinaris*) augimo charakteristikoms pusiau sausringų aukštikalnių sąlygomis]. – Both. Lith., 20(2): 99–108.

Semi-arid environments are characterized by low soil organic matter, lack of sufficient precipitation and occurrence of high temperatures at the terminal of growing season. Effects of foliar application of salicylic acid (SA) and ascorbic acid (AS) during vegetative and reproductive stages at three farmyard manure (FYM) rates (zero (FYM_1), 15 (FYM_2), 30 (FYM_3) $t \cdot ha^{-1}$) were studied on the growth and yield components of lentil (*Lens culinaris* Medik.) under supplemental irrigation of semi-arid highland in the north-west of Iran. The results revealed that application of farmyard manure especially at high level could significantly increase the morpho-physiological traits such as plant height, first pod height, plant canopy spread, rooting depth, the number of root nodules, ground cover, chlorophyll content and relative water content. Although improving effects of SA and AS on growth parameter were less than FYM, plants treated with SA showed better performance than plants treated with AS. A similar status was observed for grain yield and yield component. So the highest grain yield was recorded at FYM_3 by foliar application of SA. It can be concluded that FYM_3 as the most promising manure application rate was adopted to improve both root and total above-ground plant growth. Also this work highlights the importance of exogenous application of growth regulators in lentil cropping systems in semi-arid region with the Mediterranean climate.

Keywords: ascorbic acid, morpho-physiological traits, salicylic acid, vegetative growth, yield components.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) is an important pulse crop and is considered as one of the most ancient grain legumes of the Mediterranean region and was domesticated in the Fertile Crescent about 7000–9000 years ago (Zohary & Hopf, 2000). Thus, numerous efforts have been carried out to improve its productivity. The major lentil growing areas are in the arid and semi-arid zones of Mediterranean region, where plant experiences multiple environmental stresses such as drought, salinity and heat. Although lentil plants have an ability to create a symbiotic relationship with the bacterium *Rhizobium leguminosarum* for fixation of atmospheric nitrogen, the adverse environmental condition can negatively affect the function of this bacterium and considerably decrease biological nitrogen fixation (Marino et al., 2007).

However, breeding and selection for improved yield stability and/or potential under semi-arid zones with Mediterranean climate across lentil has shown slow progress and quite restricted advancement has been made in developing or releasing stress-tolerant cultivars. This could be due to a variety of intricacies, including absence of efficient selection criteria, complexities of the tolerance traits and time- and labour- consuming actions. For that reason, it seems that more favourable results can be achieved by adoption of the best management practices. Between the agronomical practices, the advantages of application of plant residues or farmyard manure in improving the physicochemical properties of soil have been well recognized (Rudrappa et al., 2006). Soils of semi-arid regions of Iran are intensively tilled; they are low in organic matter content and consequently have weak structural stabilities (Shirani et al., 2002). In this area, removal of straw for animal feed is common and this may indicate the importance of adding manure when straw is removed. Preservation of soil organic carbon is essential for the long-term productivity of dry land agro-ecosystems and it can improve the soil structure, water infiltration, water holding capacity, bulk density and it sustains microbial activity. In semi-arid rainfed area, soil fertility in most cases is low and it is often caused by declined organic matter or erosion of the topsoil (Adolph et al., 2002). It has been shown that farmyard manure may supply all major macronutrients (N, P, K, Ca, Mg, S) essential for plant development, as well as micronutrients (Fe, Mn, Cu and Zn). Also it may sustain soil nutrient concentration and stimulate various features of soil fertility (Satyanarayana et al., 2002).

Between various management strategies or approaches used to mitigate the adverse effect of environmental stress, exogenous application of plant growth regulators has obtained substantial consideration. There are numerous chemical compounds for alleviating effect of stress and improving plant growth. The choice of the compound depends on the environmental condition, plant species and facilities available. Salicylic acid, a common phenolic compound, is introduced as a hormone-like endogenous plant growth regulator, and seems it has some imperative functions in the defence mechanisms against biotic and environmental stressors in arid and semi-arid regions (Rivas-San Vicente & Plasencia, 2011). It also plays an important role in plant growth, development and defence responses under unsuitable conditions by influencing various physiological processes and biochemical reactions (Rivas-San Vicente & Plasencia, 2011). It has been reported that foliar application of salicylic acid on sunflower could significantly enhance biomass production, photosynthetic pigments and photosynthetic process (Ghasemzadeh & Jaafar, 2013).

Additionally, ascorbic acid (vitamin C) is evidently an omnipresent metabolite in plant cells. It can play a role of an antioxidant, enzyme cofactor and a precursor for tartrate and oxalate synthesis. It has been revealed that ascorbic acid participates in a range of processes, including photoprotection, photosynthesis, cell wall synthesis and cell expansion, protects plants against abiotic stresses and synthesis of phytohormones (ethylene and gibberellins) anthocyanins and hydroxyproline.

In spite of wide range of properties, not much agronomical studies have been conducted to explore the potential of lentil plant in a sustainable manner. Thus, this study aimed to determine the effect of different levels of farmyard manure and foliar application of salicylic acid and ascorbic acid on growth and yield components of lentil under semi-arid highland conditions.

MATERIALS AND METHODS

The experiment was carried out during growing season at the Research Field of the University of Maragheh, East Azarbaijan, Iran in 2013. The field was located at 46° 16' E, 37° 23' N, at an altitude of 1485 metres from the sea level. Maragheh is a representative of highland semi-arid zone and, according to the updated classification of Köppen and Geiger, its climate is classified as BSk; cold semi-arid climate (Peel et al., 2007) with an average annual precipitation of 353 mm, consisting of 73% of rain and 27% of snow. This district is a large elevated area and is located at the mountainous site of Sahand Mountain in north-western Iran. The region has very cold winters with minimum air temperatures falling below -15°C and the number of days with freezing temperatures exceeding 100. The average annual rainfall during the lentil growing season (March to July) was 181 mm, of which more than 89% was received from March to May. Average maximum and minimum temperature during growing season was 21°C and 8°C, respectively. Some climatic parameters during this research are given in Table 1.

The soil in the experimental field was a relatively shallow, sandy loam. It contained 0.4% of organic matter (OM), pH 7.57. The soil texture was made up of 53% of sand, 31% of silt and 16% of clay, electrical conductivity (EC) = 0.506 $ds \cdot m^{-1}$, 0.058% of

Table 1. Precipitation, mean humidity and mean temperature in crop seasons of 2013 at Maragheh station

Climatic parameters	March	April	May	June	July
Precipitation (mm)	43.8	11.42	17.77	0.25	4.06
Mean humidity (%)	50.7	44.8	36.7	26.4	28.8
Total evaporation (mm)	15	37	78	273	321
Mean temperature (°C)	9.4	14.13	20.1	25.2	28.6

nitrogen (N), 5.67% of available phosphorus (P)·kg^{-1} and 342 mg·kg^{-1} of available potassium (K), 34% total neutralizing value (TNV). Chemical properties of FYM included 0.68% of total N, 0.44% of available P and 1.08% of available K, pH 6.83.

Seeds of lentil cv. Kimia were procured from Dryland Agricultural Research Institute (DARI), Maragheh, Iran. This cultivar derived from a cross between ILL5582 (originated from Jordan) and ILL 707 (originated from Tunisia) in International Center for Agricultural Research in the Dry Areas (ICARDA).

The experiment was conducted as per two-factor factorial completely randomized block design having three plant growth regulators (control, 1 Mm salicylic acid and 1 Mm ascorbic acid) as first factor and three levels of farmyard manure (zero (FYM_1), 15 (FYM_2), 30 (FYM_3) t·ha^{-1}) as second factor, replicated thrice.

The experimental fields were ploughed two times in early autumn and two weeks before planting, subsequently the soil was harrowed twice to bring it to fine tilth. After second primary tillage operation, well-rotten farmyard manure was applied as per treatment and thoroughly mixed into the top soil. Each plot was 2.5 m long and 2 m wide (10 rows). The row spacing was 20 cm and plant-to-plant spacing within a row was 8 cm. The previous crop was garden cress (*Lepidium sativum*). Seeds were hand-sown on 18 March, at a depth of 5 cm, planting density 60 plants·m^{-2}. Plants were grown under rain-fed conditions till the end of May and supplementary irrigation was selectively applied three times during rainfall shortages and during the drought-sensitive growth stages (flowering and pod filling stages). No major insect pests or diseases were observed in the field during the lentil growth period. Twice hand weeding was carried out during the vegetative growth stages.

Salicylic acid and ascorbic acid were applied using an atomizer sprayer two times during vegetative (V_5:1st multifoliate leaf unfolded at 5th node) and reproductive (R3: pods on nodes 10–13 of primary branch visible) stages. The control plants were sprayed with tap water. During spraying the entire plant was completely wetted and excess solution was dripping.

Ground cover was evaluated at the flowering stage. The ratio of ground area (%) covered by the crop canopy was estimated visually. Five plants were randomly selected from each plot and dug out after irrigation at flat pod (R_4: pods on nodes 10–13 at full length and largely flat). Soil was guardedly washed from the roots. Rooting depth (cm) was measured and the nodules were picked from the roots and their numbers recorded for each plant.

Chlorophyll index was measured on ten leaves of a plant at each plot, using a portable chlorophyll metre (SPAD) at full bloom stage (R_2). For eliminating the border effects, lateral rows at both ends of each plot were excluded from the measurements. At physiological maturity, 10 plants were chosen at random from the harvest area to evaluate secondary branches per plant (branches subtending from the secondary stem), plant height (cm), pods per plant, grains per pod, 1000-grains weight (g), grain yield per plant (g) and dry matter yield (g·m^{-2}). Plant height was measured from ground level to uppermost point of the plant. The first pod height was measured as a distance between the first pod and the soil surface. The average canopy spread was measured from north to south (one side of canopy to the other side). Relative water content (RWC) was determined as RWC (%) = ((fresh weight – dry weight) ⁄ (turgid weight – dry weight)) × 100. Leaf samples were obtained from newly-expanded leaves. Leaves were immediately weighed (fresh weight) and then immerged in distilled water for 5 h and then turgid weight was obtained and, finally, dry weight was measured after 24 h in the oven at 75°C. The number of days from planting to harvest (when 95% of the plants begin to yellow and pods become greenish yellow) was recorded as the number of days to 95% maturity. Biological yield was obtained by cutting plants from ground level at maturity stage. Harvest index was calculated as the ratio of grain yield to the aboveground dry matter at maturity.

Data on morphological and yield characters were subjected to the analysis of variance (ANOVA) by procedure of SPSS 11.5. For a significant *F*-value, the least significant difference (LSD) was used to compare the means of the variables determined. Correlation coefficients were computed via plotting of the first two principal component analysis using Minitab version 14 (2005).

RESULTS AND DISCUSSION

The analysis of variance of the investigated morphological characters was presented in Table 2. The results showed that both farmyard manure (FYM) and growth regulators (GR) considerably affected the plant height, so that the plants grown under high level farmyard manure (FYM_3) had the greatest height. Foliar application of salicylic acid (SA) and ascorbic acid (AS) increased plant height by 9% and 11% compared to control plants, respectively (Table 2). The first pod height is an important trait for mechanical harvest.

The effect of FYM was significant for the first pod height. At the different levels of FYM, the first pod height varied from 9.4 to 15.6 cm and the lowest value was recorded at FYM_3. In this regard, Biçer & Şakar (2008) found a direct and negative effect of this trait on seed yield. Plant canopy spread notably responded to FYM and GR, however, their interactions were not significant. Plants grown at FYM_2 and FYM_3 had a wider canopy compared to the control. Foliar application of SA increased plant canopy spread up to 17% when compared to controls (Table 2). The result of analysis of variance showed that the number of secondary branches plant^{-1} slightly increased by application of FYM. Secondary (aerial) branches arise from the uppermost nodes of the main stem just below the first flowering node and there is close relationship between this trait and seed yield. When growing conditions are appropriate for an extremely high yield, the secondary branches also may produce additional seed-bearing branches.

In the present experiment, the average rooting depth (RD) at the 0–60 cm soil profile varied substantially among the FMY levels (Table 2). However, the growth regulators could not significantly affect this trait. The maximum RD was observed at FYM_3, closely followed by FYM_2 that was 91% and 62.7% longer compared to control plants, respectively (Table 2). The investigation of root number of nodules plant^{-1} showed that utilization of FYM slightly increased the number of nodules relative to the control. This was probably due to the gradual mineralization of manure and gradual slow nitrogen release or may through relieve of molybdenum deficiency. This finding further support the result of Otieno et al. (2009), who reported that the application of manure im-

Table 2. Effect of Farmyard manure and growth regulators on the morpho physiological traits of lentil (*Lens culinaris* Medik.)

Farmyard manure	PH	FPH	PCS	NSB	RD	NOD	GC	CHL	RWC	NDM
FYM_1	24.37b	14.30a	11.98c	4.05b	20.15c	17.59c	61.29c	37.00b	70.72b	120.33bc
FYM_2	25.72b	12.26ab	15.27b	5.75ab	32.80b	22.72bc	70.39b	47.16a	73.82b	126.67b
FYM_3	30.59a	10.34c	18.66a	6.37a	38.50a	28.84a	81.91a	51.60a	80.81a	138.00a
Growth regulators										
C	25.16ab	11.82	13.88b	5.18	29.38	22.09	67.89b	40.48b	72.60b	125.67
SA	27.53a	12.74	16.20a	5.38	30.04	26.46	74.82a	49.47a	77.06a	129.11
AS	27.99a	12.27	15.83ab	5.61	31.03	22.61	70.77b	46.81ab	75.68ab	130.22
Level of significance										
FYM	**	*	**	*	**	*	**	**	**	**
GR	*	NS	*	NS	NS	NS	**	**	*	NS
FYM × GR	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
CV%	15.27	10.30	6.44	13.6	9.97	21.66	16.71	12.26	4.12	11.88

C: control or no-application of growth regulator, SA: salicylic acid, AS: ascorbic acid, GR: growth regulator, PH: plant height (cm), FPH: first pod height (cm), PCS: plant canopy spread (cm), NSB: number of secondary branches, RD: rooting depth (cm), NOD: number of nodules per plant, GC: ground cover (%), CHL: chlorophyll content (SPAD unit), RWC: relative water content, NDM: number of days to 95% maturing. In a column, figures with same letter (s) or without letter (s) do not differ significantly, whereas figures with dissimilar letter are statistically different. NS = not significant, * = significant at 5% level of probability, ** = significant at 1% level of probability proved nodulation and grain yield only in a short rain season in different grain legumes including common bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), green gram (*Vigna radiate* L.) and lablab (*Lablab purpureus* L.).

Analysis of variance revealed that the main effect of FYM and GR on ground cover was significant. The highest ground cover was obtained at FYM_3 and/or foliar application of SA. Lentil (*Lens culinaris* Medik.) potentially is one of the cover crops also widely used in this system. Higher ground cover under semi-arid region seems to be most important, because it allows producers to improve their energy efficiency and by reducing the evaporation can prevent the excessive water loss.

The chlorophyll contents of the leaves of lentil plants were significantly influenced by both FYM and GR treatments. Also interactive effect of FYM × GR was significant for this trait (Table 2). The highest chlorophyll content was recorded in plant grown at FYM_3 and treated with SA and AS (Fig. 1). Leaves of the plants grown with application of FYM and GR had 19–54% more chlorophyll compared to the control. These results are also in agreement with those of Ganeshamurthy & Sammi Reddy (2000), who reported that chlorophyll content of soybean strongly increased by application of FYM. This might be due to efficient absorption and assimilation of nitrogen and by the plant, which serves as a constituent of chlorophyll in the plant tissue. In this regard, Babar et al. (2014) found that foliar application of SA had stimulatory effects on chlorophyll contents and also could increase gas exchange parameters and improved net CO_2 assimilation rate.

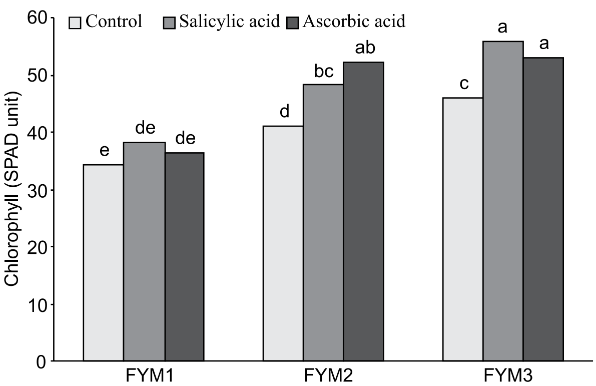

Fig. 1. Effect of exogenous application of salicylic acid and ascorbic acid on chlorophyll content of lentil (*Lens culinaris* Medik.) under three farmyard manure rates (zero (FYM_1), 15 (FYM_2), 30 (FYM_3) t·ha^{-1})

Application of FYM considerably affected the relative water content (RWC) and also significant ($p < 0.05$) differences observed in response of RWC to different growth regulators. The highest RWC was recorded in plant grown at FYM_3 and those that were sprayed with SA (Table 2). It seems that the improvement of RWC after the application of FYM is partly due to amelioration of soil physical conditions. It has been reported that FYM significantly affects soil physical properties and reduces soil compaction and bulk density; also it increases available water holding capacity in plant root zone (Tadesse et al., 2013). Furthermore, a limited degree of soil compaction under the seeding depth tends to enhance the soil moisture content near planted seeds, encouraging capillary ascent of water from subsoil (Altikat, 2013) and it can improve plant water status. RWC is positively correlated with proline and abscisic acid (ABA) concentration (Kadioglu et al., 2011). Therefore, the improvement in RWC by the exogenous application of SA may be the result of osmotic adjustment because of the accumulation of compatible solutes such as proline. Also ABA could act as anti-stress phyto-hormone and prevent water loss from the plant (Yusuf et al., 2008). Our results support the finding of Aldesuquy (2014), who reported the improvement of RWC by foliar application of SA in wheat under both well-irrigated and water-stress conditions.

Assessment of the number of days to maturity (NDM) showed that application of FYM could significantly delay maturity (Table 2). The range for NDM was 121–139 days. This finding corroborates the result of Abdullahi et al. (2013). It seems that FYM could bring a suitable condition for plant growth that resulted in long vegetative and reproductive period and greater green area duration. Farmyard manure is known to enhance soil fertility, which in turn extends vegetative growth period and maturity of crops. This partly confirmed the result of chlorophyll. The amount of chlorophyll per unit leaf area in plants is an important indicator of photosynthesis activity, stress, nutritional state and overall condition of the plant. Healthy plants capable of maximum and long growth are generally expected to have larger amounts of chlorophyll than unhealthy ones (Wu et al., 2008). Results obtained by Levey & Wingler (2005) showed that plants with late senescence produce more leaves and accumulate more chlorophyll per unit leaf area and could have prolonged vegetative growth. Changes in chlorophyll most closely are paralleled with changes in photosynthesis. Among the plant factors, reproductive growth has a recognized influence on leaf senescence. The beginning of active phase of grain filling corresponded to the beginning of the degradation of chlorophyll content and plant with higher chlorophyll could show a longer reproductive growth (Guendouz & Maamari, 2012).

The results revealed that biological yield (BY) significantly increased by both application of FYM and GR, however, their interaction was not significant (Table 3).

The amount of biological yield at FYM_2 and FYM_3 was 18% and 27% higher than control, respectively. Foliar application of SA and AS increased BY on average up to 5% when compared to intact plants. The interactive effect of FYM × GR was significant ($p < 0.05$) for straw yield. The highest straw yield was obtained from plant grown at FYM_3 without GR foliar application (Fig. 2). Lentil straw is a valued animal feed and income from straw is very important during the dry years. However, it has been revealed that the strongest determinants of lentil straw yields under rainfed conditions are total amount and distribution of rainfall during growing season, water holding capacity (amount of soil water) and temperature fluctuation, particularly at flowering and podding stages (Sarker et al., 2003). The amount of soil water that can be used by the plant varies due to the characteristics of soil (e.g. texture) and of the plant (e.g. root distribution and depth). The increase of lentil straw yield by application of FYM in the current study seems to be due to the enhancement of rooting depth and improvement of soil water availability for plants. The analysis of variance for yield components showed that 100-grain weight, the number of pod per plant, the number of grain per pod and the number of grain per plant significantly responded to FYM application, since the highest values were observed at FYM_3. It also became clear that application of GR could considerably increase the number of pod per plant and the number of grain per plant (Table 3). All of these effects reflected on grain yield, where the interactive effect of FYM×GR was significant. Mean comparison for grain yield showed that although the both application of FYM and GR increased this important trait, the best performance was recorded for plant grown at FYM_3 and treated with SA (Fig. 3). A similar trend was observed for harvest index (HI), so that plant treated with SA and AS at FYM_3 showed the highest HI (Table 3).

Relationship between physiological and yield contributing characters was studied through the analysis of correlation between them (Table 4). Grain yield·plant^{-1} positively correlated with pod·plant^{-1},

Table 3. Effect of different growth regulators and level of farmyard manure on grain yield and yield components of lentil (*Lens culinaris* Medik.)

Farmyard manure	BY	STW	HGW	NPP	NGP	GPP	HI	GY
FYM_1	2838b	1977b	29.68a	38.11c	1.133b	42.68c	28.29ab	803.72c
FYM_2	3609a	2632a	30.72ab	55.66b	1.223ab	56.22b	26.87b	970.27b
FYM_3	3713a	2603a	31.82a	66.44a	1.293a	67.55a	29.42a	1090.22a
Growth regulators								
C	3212b	2416	30.34	46.88b	1.162	48.00c	25.71b	851.62b
SA	3436a	2404	31.09	58.55a	1.261	61.77a	29.42a	1009.13a
AS	3364ab	2392	30.80	54.77a	1.227	56.68b	29.45a	1003.45a
Level of significance								
FYM	**	**	**	**	**	**	**	**
GR	*	NS	NS	**	NS	**	**	**
FYM× GR	NS	*	NS	NS	NS	*	NS	NS
CV%	6.38	13.42	3.04	10.68	7.12	15.59	11.55	18.44

C: control or no-application of growth regulator, SA: salicylic acid, AS: ascorbic acid, GR: growth regulator, BY: biological yield (kg·ha^{-1}), STW: straw yield (kg·ha^{-1}), HGW: 100 grain weight (g), NPP: number of pod per plant, NGP: number of grain per pod, GPP: number of grain per plant, HI: harvest index (%), GY: grain yield (kg·ha^{-1}). In a column, figures with same letter (s) or without letter (s) do not differ significantly, whereas figures with dissimilar letter are statistically different. NS = not significant, * = significant at 5% level of probability, ** = significant at 1% level of probability grain·pod^{-1}, grain·plant^{-1}, 100 grain weight, rooting depth, chlorophyll content, relative water content and plant canopy spread. Grain yield was determined by sink-source interactions. The result suggested that the increase of sink size (e.g. pod·plant^{-1}, grain·pod^{-1}, grain·plant^{-1} and 100 grain weight) along with the increase in the size (e.g. plant canopy spread) or activity of the source (e.g. chlorophyll content) could result in improved yield. These results are in agreement with the result of Mondal et al. (2013), who also observed that seed yield increased with increased sink and source strength in lentil.

Furthermore, the principle component analysis (PCA) described a suitable amount of the total variation (84% and 10% for PCA1 and PCA2, respectively), the correlation coefficient between any two traits is approximated by the cosine of the angle between their vectors. In Fig. 4, the most prominent relations are: a strong positive association among grain yield, the number of pod·plant^{-1}, the number of grain·plant^{-1}, 100-grain weight, plant canopy spread, plant height, relative water content, chlorophyll content, ground cover and the number of days to maturity; among biological yield, the number of nodules·plant^{-1}, the number of secondary branches·plant^{-1}, first pod height and straw yield as indicated by the small obtuse angles between their vectors (r = cos 0 = +1). Grain yield being a complex and multifaceted trait is

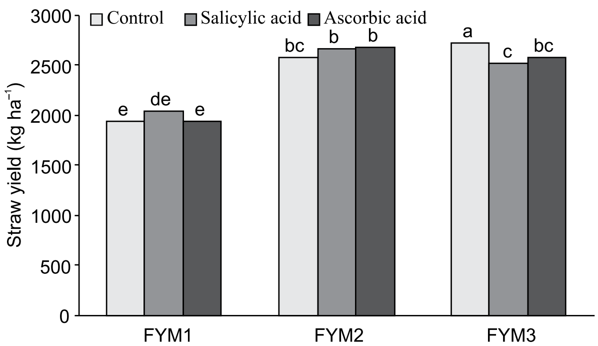

Fig. 2. Effect of exogenous application of salicylic acid and ascorbic acid on straw yield of lentil (*Lens culinaris* Medik.) under three farmyard manure rates (zero (FYM_1), 15 (FYM_2), 30 (FYM_3) t·ha^{-1})

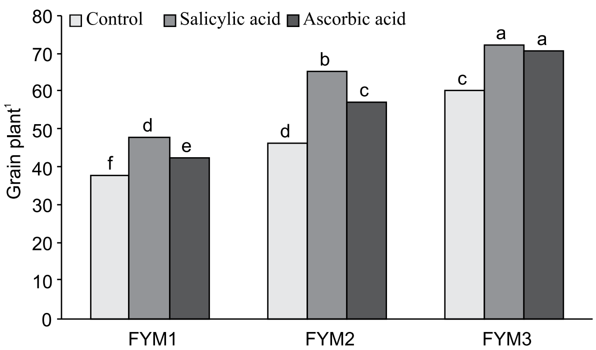

Fig. 3. Effect of exogenous application of salicylic acid and ascorbic acid on grain number per plant in lentil (*Lens culinaris* Medik.) under three farmyard manure rates (zero (FYM_1), 15 (FYM_2), 30 (FYM_3) t ha^{-1})

Table 4. Pearson's correlation coefficients among 17 traits of lentil

	BY	STY	GY	HI	HGW	GC	NSB	NDM	NPP	NGP	GPP	PH	FPH	PCS	RD	NOD	CHL
STY	0.98†																
GY	0.86	0.72															
HI	0.10	-0.12	0.60														
HGW	0.89	0.78	0.95	0.45													
GC	0.85	0.74	0.93	0.46	0.98												
NSB	0.98	0.93	0.89	0.18	0.92	0.89											
NDM	0.80	0.68	0.91	0.51	0.95	0.96	0.87										
NPP	0.91	0.81	0.96	0.42	0.95	0.96	0.93	0.89									
NGP	0.86	0.73	0.98	0.55	0.96	0.95	0.87	0.88	0.98								
GPP	0.86	0.73	0.97	0.53	0.96	0.95	0.87	0.89	0.98	0.98							
PH	0.68	0.53	0.88	0.66	0.90	0.91	0.77	0.95	0.84	0.87	0.84						
FPH	0.92	0.87	0.85	0.22	0.88	0.89	0.93	0.88	0.88	0.83	0.81	0.79					
PCS	0.88	0.77	0.96	0.48	0.98	0.98	0.92	0.96	0.97	0.97	0.96	0.93	0.89				
RD	0.97	0.93	0.85	0.13	0.89	0.89	0.98	0.86	0.93	0.86	0.86	0.74	0.92	0.91			
NOD	0.79	0.75	0.73	0.20	0.80	0.84	0.78	0.70	0.84	0.83	0.77	0.73	0.74	0.84	0.82		
CHL	0.88	0.77	0.96	0.48	0.88	0.89	0.90	0.84	0.97	0.95	0.93	0.81	0.86	0.92	0.89	0.77	
RWC	0.75	0.60	0.92	0.62	0.95	0.97	0.80	0.97	0.90	0.92	0.92	0.97	0.82	0.96	0.79	0.77	0.83

† Critical values of correlation $p < 0.05$ and $p < 0.01$ (D.F. 7) are 0.66 and 0.79, respectively

an ultimate expression of different yield components and management practices. This result may indicate that there is interrelationship between the developmental and productive traits and this can be important for formulating effective breeding programmes. It is encouraging to compare this finding to that found by Mekonnen et al. (2014), who by multivariate analysis found that the most important traits that contributed to the genetic divergence in order of importance were seed yield, above ground biomass, days to 90% maturity, the number of seeds per plant and the number of pods per plant. These agro-morphological traits can be used as a basic character for developing lentil performance in semi-arid region.

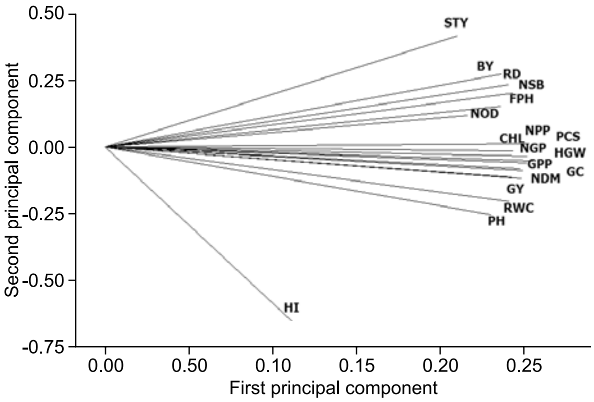

Fig. 4. The principle component analysis (PCA) for morpho-physiological traits of lentil under different levels of application of farmyard manure and foliar growth regulators in supplementary irrigation system

CONCLUSIONS

In conclusion, this research demonstrated that the growth parameters and yield components of lentil were influenced by the application of farmyard manure and growth regulators. In general, the beneficial influences of farmyard manure on growth yield and yield attributes was apparent with increasing levels of application. On the basis of these experimental findings, it seems that the productivity of lentil plant can be maximized by use of 30 $t \cdot ha^{-1}$ farmyard manure combined with foliar application of salicylic acid. Generally, it could be concluded that soil amendment with proper level of farmyard manure and foliar spraying of growth regulators are relatively cost-effective ways to increase soil organic matter content, stimulate plant growth, improve rooting depth and ultimately improve lentil yield in the semi-arid highland environment.

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MĖŠLO IR AUGIMO REGULIATORIŲ POVEIKIS LĘŠIŲ (*LENS CULINARIS*) AUGIMO CHARAKTERISTIKOMS PUSIAU SAUSRINGŲ AUKŠTIKALNIŲ SĄLYGOMIS

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Santrauka

Pusiau sausringiems regionams būdingas mažas kritulių kiekis, aukšta vegetacijos periodo temperatūra ir nepakankamas organinės medžiagos kiekis dirvožemyje. Tirta lęšių (*Lens culinaris* Medik.), kurių lapai buvo apdoroti salicilo ir askorbo rūgštimis, augimo ir derliaus rodiklių bei tręšimo mėšlu normų priklausomybė bandymuose, atliktuose pusiau sausringame šiaurės vakarų Irano regione, taikant papildomą drėkinimą.

Rezultatai parodė, kad tręšimas mėšlu, ypač taikant dideles normas, žymiai padidino pagrindinius augimo požymius, tokius kaip aukštis, lapijos plotas, šaknų gylis ir jų gumbelių skaičius, chlorofilo ir santykinio vandens kiekis. Nustatyta, kad salicilo ir askorbo rūgščių įtaka augalams buvo mažesnė nei mėšlo, tačiau augalai apdoroti salicilo rūgštimi reikšmingai skyrėsi didesniais augimo bei derliaus rodikliais nei apdoroti askorbo rūgštimi. Didžiausias grūdų derlius buvo nustatytas bandyme, taikant didžiausią tręšimo mėšlu normą. Tręšimas mėšlu pagerina augalų antžeminių ir požeminių organų augimo charakteristikas, tačiau augimo reguliatorių taikymas jas reikšmingai sustiprina. Toks tręšimo schemos taikymas ypač svarbus vystant lęšių auginimo sistemą pusiau sausringuose aukštikalnių regionuose.