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Growth and photosynthesis of three henna (*Lowsonia inermis* L.) ecotypes at different planting densities

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ABSTRACT

Lowsonia inermis L., commonly known as henna is a medium sized shrub, used for its medical and cosmetic virtue and is one of the chief sources of natural dye. The aim of this study was to examine the influence of planting density (25, 33.3, 50, and 100 plants m^{-2}) and ecotype (Bam, Roodbar and Shahdad) on growth indices, photosynthesis parameters and biomass production of henna. The experiments were carried out in two years (2015 and 2016, during February-November) and in two environments (Kerman and Shahdad). The results indicated that the leaf dry yield, total dry yield, crop growth rate and leaf area index significantly ($p < 0.01$) increased with increasing in plant density while leaf dry weight, total dry weight, leaf area duration and biomass duration decreased. The highest planting density in combination with the Shahdad ecotype produced the highest leaf area index. The crop growth rate and leaf area index of henna plants were higher in Shahdad environment than Kerman environment. Multiple regression analysis showed that crop growth rate (in Shahdad environment) and leaf area index (in Kerman environment) had the maximum effect on leaf dry yield of henna compared with the other measured parameters and might be effective means to increase leaf production of henna.

1. Introduction

Henna (*Lowsonia inemis* L.) is a perennial plant of family Lythraceae with medicinal and industrial applications. The plant symbolizes auspiciousness, prosperity, and happiness in South Asian countries like India, Pakistan, Iran and UAE and is widely used in a variety of religious and ritualistic ceremonies of Hindu and Muslim communities (Kumar Singh et al., 2015). The leaves are used as prophylactic in opposition to boils, burns, bruises, inflammations of skin and also against sore esophagus (Rout et al., 2001). The dried leaf-yield in the first year of cultivation is around 200 kg ha^{-1} while in the years after, the yields normally range from 1000 to 1500 kg ha^{-1} with three cropping per year (Farooqi and Sreeramu, 2004). Deep, fine sandy or medium-textured, well-drained soils are best for henna development (Rao et al., 2002). A henna leaf produces the highest dye content in temperature between 35–45 °C. Henna does not thrive where minimum temperatures are below 11 °C and temperatures below 5 °C will kill the henna plant (Yadav et al., 2013). Tremendous efforts have been made to study the effect of planting density on biomass accumulation and yield in plants while there are very little researches on this valuable plant regarding its husbandry practices and as such the present study is unique and unprecedented in its kind and definitely there are no published reports that investigated growth indices and photosynthetic parameters of henna under field condition. The purpose of this research was to determine (1) if growth indices and photosynthesis parameters varied among the three henna ecotypes grown in field, (2) if these parameters were influenced by the planting densities, and (3) which parameters might be more effective on leaf production of henna and can be considered as a practical basis for the establishment of henna cultivation.

2. Materials and methods

2.1. Experimental site

Two field experiments were conducted in 2015 and 2016 during February-November in two region of Kerman province, Iran. The first experiment was carried out at the research farm of Shahid Bahonar University of Kerman, Iran situated at 30°14′N latitude, 57°7′E longitude with an elevation of about 1753 m above mean sea level. The second experiment was performed in the experimental site of Shahdad Agricultural and Natural Resources Research Center (30°23′N, 57°45′E and altitude 450 m), Kerman, Iran. Maximum and minimum

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Table 1
Monthly values of maximum and minimum air temperature and rainfall of the years 2015 and 2016 for both experiments.

Year	Month	Kerman			Shahdad		
		Air temperature (°C)		Rainfall (mm)	Air temperature (°C)		Rainfall (mm)
		Max	Min		Max	Min	
2015	Jan	24.4	−9.5	19.41	29.0	5.0	4.9
	Feb	23.0	−5.0	14.42	30.0	5.2	13.0
	Mar	26.2	−6.5	49.8	33.8	6.0	7.0
	Apr	32.6	6.0	0.42	42.8	15.0	2.01
	May	35.8	9.0	3.42	45.0	23.0	5.30
	Jun	39.1	12.0	0	48.0	29.0	0
	Jul	37.4	13.5	1.51	47.0	30.4	0
	Aug	37.5	9.9	0	46.4	28.0	0
	Sep	35.6	6.0	0.91	42.0	22.0	0
	Oct	32.6	1.6	0.10	41.0	18.8	0.01
	Nov	27.8	−5.4	26.51	28.0	10.0	4.01
	Dec	26.0	−8.9	29.30	27.0	2.80	7.0
2016	Jan	16.74	−1.35	11.2	20.41	10.28	2.01
	Feb	18.78	−0.19	17.3	23.23	12.29	1.0
	Mar	21.5	5.50	14.83	28.50	17.74	0.01
	Apr	24.97	7.41	5.11	33.33	22.39	0.52
	May	33.04	14.21	7.30	41.51	30.87	0.51
	Jun	34.73	15.63	0	43.65	31.74	0
	Jul	37.55	19.8	1.90	46.26	34.23	0
	Aug	32.67	13.58	0	41.90	29.70	0
	Sep	35.02	14.19	0	42.30	30.13	0
	Oct	27.95	7.78	0	33.67	22.24	0
	Nov	20.62	0.90	1.91	23.23	12.80	0.80
	Dec	20.41	0.24	0	21.61	11.18	0

Table 2
Soil properties at the beginning of the growing season.

	Soil texture	Nitrogen (%)	Phosphorus (mg kg^{-1})	Potassium (mg kg^{-1})	pH	EC (dS m^{-1})	Organic matter (%)
Experiment one	Sandy-Loam	0.05	16	242	8.07	4.31	0.06
Experiment two	Sandy-Loam	0.03	13.5	231.5	7.98	4.18	0.05

temperature and precipitation of the years 2015 and 2016 for both experiments are presented in Table 1. The previous crop for both first and second experiments was wheat harvested on July 2014 and May 2014 respectively. The soil characteristics of the experimental sites are shown in Table 2.

2.2. Experimental design

Two factorial experiments based on randomized complete block design with four densities (25, 33.3, 50 and 100 plants m^{-2}); three ecotypes (Bam, Roodbar and Shahdad) and three replicates were carried out. The henna seeds were manually sown in seedling trays (each including 105 cells with 40 mm depth, 36 mm diameter, and 20 cm^3 volume that were filled with a mixture of cocopeat and sand) on 15 February (2014 and 2015) in the greenhouse conditions (14 h photoperiod, 60% relative humidity and 25/22 °C day/night). The seedlings were irrigated with tap water during the first 5 days and then with a Hoagland solution, pH 6.2–6.5. At the five-leaf growth stage, seedlings were transferred to the field and adjusted for precise planting density. Each experimental unit had an area of 4.0 m^2 (2.0 m long and 2.0 m wide) and the net area used for harvesting was 2.0 m^2 to eliminate the edge effects. Urea containing 46.7% nitrogen was used as the nitrogen source, and the application of base fertilizer, seedling and flowering fertilizer followed the ratio of 2:1:2. The sources of P_2O_5 and K_2O were single superphosphate (14% P_2O_5) and potassium chloride (60% K), respectively. Phosphorus and potassium fertilizers were all applied before transplanting. Combined analysis of variance for two year data (2015 and 2016) was performed for each environment (Kerman and Shahdad) separately.

2.3. Measured items

Plots were harvested on 25 November when approximately 2/3 of bolls were brown. The aboveground tissues were dried in an oven for 30 min at 105 °C to deactivate enzymes and then dried at 80 °C until a constant weight was reached for dry yield determination. Five plants were randomly selected from each plot before flowering stage to measure the growth indices. The leaf area of the ecotypes was measured using the leaf area meter (WINAREA-UT-11, Iran). The growth indices, including crop growth rate (CGR), relative growth rate (RGR), leaf area index (LAI), leaf area ratio (LAR), specific leaf area (SLA), specific leaf weight (SLW), leaf area duration (LAD) and biomass duration (BMD) were calculated using equations presented by Gardner et al., (1985). Net photosynthesis rate (P_n), leaf stomatal conductance (C_{leaf}), and transpiration rate (E) were measured using a Handheld Photosynthesis System (Cl-340, CID Bio-Science, USA). For this purpose 5 plants were selected (fully expanded young leaves) from the center row of each plot and all measurements were conducted on the onset of flowering stage in August.

2.4. Data analysis

Combined analysis of variance (ANOVA) was performed using SAS (ver. 9.2, 2010). The means of treatments were compared by the protected least significant difference (LSD) procedure at $P < 0.05$. Multiple regression analysis (stepwise method) was performed using LDY as dependent variable and the other parameters as independent variables. Since the variables are not in the same unit of measures, a