Indian J. Genet., 69(2): 140-144 (2009)

Variability and stability of genotypic performance in Henna (*Lawsonia inermis* L.) under semi-arid conditions of Rajasthan

P. K. Roy[1] and S. K. Jindal[2]

[1]Regional Research Station, Central Arid Zone Research Institute, Pali 306 401
[2]Division of Plant Sciences and Biotechnology, Central Arid Zone Research Institute, Jodhpur 342 003

(Received: January 2009; Revised: April 2009; Accepted: May 2009)

Abstract

Ten genotypes of henna (*Lawsonia inermis* L.), a popular leaf-based dye crop, were evaluated for five growth and yield traits and for leaf dye content in three years of re-growth under rainfed conditions at two semi-arid locations differing in soil characteristics. Pooled ANOVA over the environments revealed significant variation among the genotypes for plant height, dry leaf yield, stem yield and seed yield per plant. Location x year interaction effect was evident for all the traits. Dry leaf yield per plant recorded significant variation due to genotype x year interaction. Genotypic differences were non-significant for lawsone dye content in leaves which, however, showed significant variation due to year of production. The dye content in leaves appeared to be higher in year recording longer sunshine hours during crop period. Stability analysis conducted for dry leaf yield indicated similar response of the genotypes to environment with highest b_i value recorded by S-8 accession. Among the genotypes S-8 and S-21 alone recorded significant deviation from regression. These genotypes produced high dry leaf yield per plant but, as desired, low seed production was found in S-8. Overall, S-8 was considered most superior among all genotypes for leaf production under the semi-arid environment.

Key words: Henna, variability, stability, leaf yield, lawsone dye content, sunshine hours

Introduction

Henna is a leaf-based perennial dye crop of Rajasthan. It is mainly grown in Pali district over about 35000 ha yielding about 90 per cent of the total produce of the country. Young, 3-4 month-old seedlings raised in nursery are transplanted during monsoon to raise the crop stand which is coppiced thereafter every year for production of leaves [1]. The coppice shoots that develop every year during the rainy season are harvested in September or October depending on the withdrawal of monsoon. The hot and dry agro-climate of Western Rajasthan is particularly conducive for the production of good quality henna leaves used as herbal dyestuff for hair coloring and body art. Lawsone is the principal dye compound found in henna leaves.

The plant is a self-pollinated woody shrub. There is limited information on the variability in this crop essential for genetic improvement. Whereas significant variation was reported in the performance of clonal populations [2, 3] the variability in the populations of seedling origin used in commercial planting has not been studied. The present work was therefore taken up to assess the variability and stability of performance of diverse seedling accessions of henna under semi-arid growing conditions. These accessions originated from diverse henna seedling nurseries in Pali region in Rajasthan which is considered to be an important centre of diversity of cultivated henna in the country.

Materials and methods

Plants of ten diverse seedling accessions of henna having broad leaves were raised from bulk seed and evaluated over three years of re-growth (2004-06) after field establishment at two experimental sites, located in Pali-Marwar and Jadan, in the semi-arid district of Pali in Rajasthan. The former site located in the research farm of Regional Research Station, C.A.Z.R.I. at Pali-Marwar has sandy clay loam of moderate depth (45-50 cm) with about 0.45 % soil organic carbon and 12.5 kg/ ha available P; it is underlain by an impervious calcarious nodular sub-strata. In contrast, the later site located in the Range Management and Soil Conservation Centre of C.A.Z.R.I. at Jadan, about 20 km from the former site, has loamy sand of shallow depth (less than 30 cm) with lower organic carbon (about 0.25%) and available P (about 6.5 kg/ ha); it is underlain by permeable slatey rock sub-strata. The soil at both sites has 8.6 to 8.9 pH.

The experimental sites thus differed in soil texture, soil depth, organic carbon content, P availability and general soil moisture storage potential which increase with heavier soil texture and greater soil depth. The experimental years showed similar temperature regimes and humidity conditions but varied with respect to receipt of rainfall and sunshine hours during the crop duration as per weather data recorded at Pali-Marwar (Table 1). The weather at Jadan location during the study years was similar to that at Pali-Marwar in view of its physical proximity.

Seedlings of the test genotypes were raised in earthen pots filled with normal potting mixture. With the onset of monsoon in 2003 the seedlings attaining 4 months age were uprooted and after cutting back of the tap root to about 15 cm length were transplanted in field at each location. The seedlings were transplanted in single 7.2 m long rows maintaining 60 cm plant to plant and 90 cm row to row distance under Completely Randomized Block Design layout with three replications. After the establishment year the crop was taken rainfed for three subsequent years of re-growth (2004-06) with one or two inter-culture operations and top dressing of 60 kg N/ ha during the growing season.

Observations were recorded at harvest on the plant height (PH) in cm, main branches (MB), dry leaf yield (DLY), dry stem yield (DSY) and seed yield (SY) in g, and the lawsone content (LC) of dried leaves in mg/g content of three randomly selected plants from each genotype during the subsequent three years of re-growth (2004-06) except for seed yield which was recorded only in 2005 and 2006. Lawsone content of henna leaves was estimated using the method of BIS [4]. Mean data were subjected to ANOVA in each of the six test environments as well as over the environments. The characters exhibiting significant interaction of genotypes with either location or/ and year were further subjected to stability analysis as per the method of Eberhart & Russell [5].

Results and discussion

Variation in plant growth attributes and productivity

Pooled ANOVA over the environments revealed highly significant variation due to years and non-significant variation due to locations for plant height, main branches, dry leaf yield, dry stem yield and seed yield/ plant (Table 2). Genotype mean squares were significant for all these traits at either 5% or 10% level of probability except for main branches/ plant.

The results indicated that year had major effect on all the above plant growth and production traits while location had minor influence. However, the significance of location x year interaction effect found for these traits (Table 2) suggested some modifying influence of location on plant performance in different years. It could be due to variation in the soil characteristics of experimental fields. Significant genotype x year interaction was found for dry leaf yield alone. This indicated that relative performance of genotypes varied with year irrespective of location probably caused by differences in genotypic response to seasonal weather in different years. Among the traits only dry stem yield and seed yield showed significant genotype x location interaction. It suggested that the location had dissimilar effect on the expression of these traits in different genotypes.

Perusal of the mean performance of genotypes in different years over locations (Table 3) revealed that there was progressive and significant increase in all the plant growth and production traits except seed yield during the years of study. Whereas seed yield was greater in year (2005) with higher rainfall the trend in case of other traits including dry leaf yield appeared to

Table 1. Mean daily weather parameters recorded during crop period at Pali-Marwar, Rajasthan (figures in parenthesis indicate range of values or dates)

Year	Crop period (start of rainfall – harvest date)	Temperature (°C) Max.	Temperature (°C) Min	R.H. (%)	Total Rainfall (mm)	Sunshine hours Mean	Sunshine hours Total
2004	106 days (09 Jun-22 Sep)	35.20 (24.6-42.7)	25.95 (21.5-30.9)	66.33 (41.5-97.5)	309	7.03 (0.0-11.2)	745.1
2005	123 days (22 Jun-22 Oct)	35.19 (29.5-42.8)	24.57 (13.6-30.1)	64.86 (32.5-96.5)	527.8	7.37 (0.4-11.6)	906.7
2006	107 days (25 Jun-09 Oct)	34.45 (25.1-44.5)	25.09 (14.1-31.5)	68.30 (36.0 – 99.0)	462.5	5.65 (0.0-11.0)	604.4

Table 2. Pooled ANOVA mean squares for five growth and yield traits of henna#

Source	d.f.$	Plant height	Main branches	Dry leaf yield	Dry stem yield	Seed yield
Locations (L)	1(1)	24384.869 ns	24.119 ns	1833.870 ns	26856.143 ns	2842.425 ns
Years (Y)	2(1)	10061.951**	334.756**	18259.976**	65288.812**	3415.787**
Genotypes (G)	9(9)	291.403*	1.906 ns	324.093 @	654.083*	180.234*
L x Y	2(1)	2304.170**	83.641**	3421.245**	14378.945**	731.960**
G x L	9(9)	240.255 ns	1.053 ns	143.663 ns	762.124**	218.556*
G x Y	18(9)	133.309 ns	1.027 ns	161.292*	242.808 ns	28.791 ns
G x L x Y	18(9)	81.507 ns	0.974 ns	171.771*	437.531 ns	27.781 ns
Error (pool)	108(72)	145.062	1.419	91.970	277.397	68.333

#Mixed effects model followed with locations and genotypes having fixed effect and year having random effect
$Degrees of freedom for seed yield are given in parenthesis
*,** and @indicate significance at 5%, 1% and 10% probability level, respectively
nsindicates non-significance at 5% probability level

be unrelated to rainfall received during crop period in the different years (Table 1). However, significant variation in dry leaf yield due to variation in amount and distribution of rainfall have been reported [6]. The overall increase in the expression of all growth or production traits except seed yield from one to the next year in this study could be mainly due to the increasing age of the plants.

Mean genotypic performance across the years and locations are given in Table 4. The mean plant height of the accessions ranged from 83.31 cm to 95.52 cm, main branches from 6.01 to 7.15/plant, dry leaf yield from 24.43 g to 39.42 g/plant, dry stem yield from 45.08 g to 65.30 g/plant and seed yield from 5.23 g to 15.80 g/ plant. Genotypes S-17, S-8 and M-1 recorded above average mean plant height from 92.0 to 95.52 cm and appeared taller than other genotypes. Genotype S-5 recorded the minimum plant height (83.31 cm).

For dry leaf yield, S-21 was the most productive (39.42 g/plant) followed by S-7 (39.15 g/plant) and S-8 (36.48 g/plant). The minimum mean dry leaf yield (24.43 g/plant) was recorded by S-22. Population S-8 produced highest dry stem yield (65.30 g/plant) at par with S-7 (63.22 g/plant), M-1 (62.80 g/plant) and S-21 (61.72 g/ plant), whereas the lowest mean dry stem yield was recorded by S-22 genotype (45.08 g/plant). With respect to seed production, S-21 showed highest mean seed yield (15.80 g/plant) followed by S-7 (14.62 g/plant) and S-18 (10.88 g/plant) whereas S-17 produced minimum seed yield (5.23 g/plant) followed by S-8 (5.47 g/ plant).

Based on the mean performance over the two test locations and three growth cycles, genotype S-8,

Table 3. Mean performance of henna plants over two locations in different years

Year	PH	MB	DLY	DSY	SY	LC
2004	75.33	4.84	18.83	22.27	-	25.51
2005	90.10	5.56	31.46	67.33	14.42	28.98
2006	101.15	9.25	51.32	86.54	3.75	21.55
Mean	88.86	6.55	34.54	58.71	9.08	25.35
$SE_m \pm$	0.64	0.15	1.24	2.15	1.31	0.30
CD 5%	4.37	0.43	3.48	6.05	3.68	0.85

Table 4. Mean performance of henna plants over two locations and three years

Acce-ssion	PH	MB	DLY	DSY	SY*	LC
M-7	90.23	6.27	35.78	60.87	9.70	25.63
S-17	95.52	6.49	35.78	58.38	5.23	26.59
S-22	85.52	6.01	24.43	45.08	6.31	25.30
S-8	94.17	7.15	36.48	65.30	5.47	25.75
S-5	83.31	6.50	35.25	51.90	10.56	24.72
M-1	92.00	6.89	33.08	62.80	5.66	24.71
M-9	88.48	6.57	32.33	58.43	6.58	24.86
S-18	87.15	6.28	33.72	59.45	10.88	25.95
S-7	87.62	6.68	39.15	63.22	14.62	25.07
S-21	85.63	6.67	39.42	61.72	15.80	24.91
Mean	88.86	6.55	34.54	58.71	9.08	25.35
$SE_m \pm$	2.84	0.28	2.26	3.93	2.39	0.55
CD 5%	7.99	ns	6.36	11.05	6.72	ns

*mean of two years only (2005 and 2006).

showing both high leaf yield and low seed yield as desired, was identified as the most promising high yielding accession.

Variation in lawsone content

The lawsone (dye) content of dry leaves showed significant mean squares due to years at either location as well as over locations while those due to genotypes were non-significant (Table 5). In pooled variance analysis the effect of locations appeared to be non-significant. The interaction effect of genotypes with location or/ and years were non-significant while location x year interaction effect was found significant These indicated that lawsone dye content, the principal quality parameter of this crop, was significantly influenced by weather but not by genotype or local soil conditions.

Over the different environments, mean lawsone content of the genotypes ranged from 24.71 mg to 26.59 mg/ g dry leaf weight (Table 4). Among the years (Table 3), leaves produced in 2005 recorded the highest mean dye content (28.98 mg/g) followed by those of 2004 (25.51 mg/g) and 2006 production year (21.55 mg/ g). This trend appeared to be directly related to the variation in sunshine hours recorded during the crop duration among the different years (Table 1). As the dye content was higher in year recording longer daily or total sunshine hours it could be concluded that longer sunshine hours during crop growth may lead to greater synthesis of dye in henna leaves under rainfed semi-arid growing conditions.

Stability of genotypes

In view of the significant interaction of genotypes with environment (either year or location) for dry leaf yield and dry stem yield the data on these traits were subjected to stability analysis [5].

Table 5. Individual location and pooled ANOVA mean squares for lawsone dye content of henna

Source	d.f.$^{\$}$	Pali	Jadan	Pool
Locations (L)	1	-	-	142.380 ^{ns}
Years (Y)	2	517.746**	345.163**	827.800**
Genotypes (G)	9	13.273 ^{ns}	4.055 ^{ns}	6.869 ^{ns}
L x Y	2	-	-	35.109**
G x L	9	-	-	10.458 ^{ns}
G x Y	18	4.462 ^{ns}	3.855 ^{ns}	2.999 ^{ns}
G x L x Y	18	-	-	5.318 ^{ns}
Error (pooled)	108(54)	6.612	4.425	5.519

$^{\$}$error d.f. for individual location given in parenthesis
**Significant at 1% probability level; ^{ns}non-significant

Table 6. Stability analysis mean squares for dry leaf yield and dry stem yield of henna

Source	d.f.	Dry leaf yield	Dry stem yield
Genotype	9	108.055*	218.251*
Environment + (Genotype x environment)	50	350.229	1370.585
Environment (linear)	1	15082.437	62124.396
Genotype x environment (linear)	9	49.136 ^{ns}	84.212 ^{ns}
Pooled deviation	40	49.670$^{@}$	141.174 ^{ns}
M-7	4	13.905	125.083
S-17	4	48.832	118.294
S-22	4	20.290	42.340
S-8	4	98.370*	160.090
S-5	4	61.532	131.932
M-1	4	31.605	223.060$^{@}$
M-9	4	32.637	85.623
S-18	4	41.810	251.023$^{@}$
S-7	4	67.262	237.650$^{@}$
S-21	4	80.455$^{@}$	36.641
Pooled error	120	36.116	104.257

* and $^{@}$Significance at 5% and 10% probability level
^{ns} non-significance at 5% probability level

The genotypic regression coefficients (b_i) varied from 0.594 (S-22) to 1.237 (S-8) for dry leaf yield and from 0.811 (S-22) to 1.211 (M-1) for dry stem yield. The genotype x environment (linear) mean squares were found to be non-significant for both the productivity traits (Table 6) indicating lack of differences in the regression of the genotype on environment for these traits. In other words, the test genotypes showed similar response to the different environments for the expression of dry leaf or stem yield.

The mean squares due to pooled deviations were significant at 10% probability level for dry leaf yield but non-significant for dry stem yield. This suggested some genotypic differences in the non-linear regression for dry leaf yield. Genotype S-8 and S-21 recorded significant deviation from regression (at 5% or 10% probability level) and accordingly appeared to be less stable for dry leaf yield compared to other genotypes under the experimental conditions.

Acknowledgement

The study was formulated and initiated under AP Cess Ad hoc Scheme of ICAR entitled 'Development of Agro-techniques for Henna (*Lawsonia inermis* L.) Production'. The financial assistance of ICAR received for this study is thankfully acknowledged.

References

1. **Rao S. S., Roy P. K., Regar P. L. and Khem Chand.** 2002. Henna cultivation in arid fringes. Indian Farming, **52**: 14-20.
2. **Singh M., Jindal S. K. and Singh D.** 2005. Natural variability, propagation, phenology and reproductive biology of henna. *In*: Henna – Cultivation, Improvement and Trade (eds. Manjit Singh, Y. V. Singh, S. K. Jindal and P. Narain). Central Arid Zone Research Institute, Jodhpur: 13-18.
3. **Singh M., Jindal S. K. and Sivadasan R.** 2008. Genetic variability in the germplasm of mehndi (*Lawsonia inermis*). Annals of Arid Zone, **47**: 151-154.
4. **BIS.** 1985. Indian Standard Specification for Henna Powder (IS: 111421984). Bureau of Indian Standards, New Delhi, pp. 8.
5. **Eberhart S. A. and Russell W. L.** 1966. Stability parameters for comparing varieties. Crop Science, **6**: 36-40.
6. **Rao S. S., Roy P. K. and Regar P. L.** 2003. Effect of crop geometry and nitrogen on henna leaf production in arid fringes. Indian Journal of Agricultural Sciences, **73**: 283-285.