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Correlation and Path Analysis for Biochemical and Micronutrient Content of Mulberry (*Morus alba* L.) under Alkali Affected Area in South India

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A B S T R A C T

The objective of this study was to determine correlation and path analysis for biochemical and micronutrient content of mulberry. The study was taken up with untreated alkali soils, alkali soils reclaimed with inorganic and organic amendments in Karnataka, South India by growing five alkali tolerant mulberry genotypes along with two improved genotypes and one ruling local check. Mulberry genotypes were significantly varied ($p<0.01$-0.05) in biochemical and micronutrient content. In addition, biochemical parameters such as total protein content, total carbohydrate content, mineral content, reducing sugar content, iron, zinc and copper exhibited positive and significant correlation at both phenotypic as well as genotypic level with leaf yield under test condition. The determination of genotype x environment interaction of alkali tolerant mulberry genotypes were studied.

Key words: Correlation, Path analysis, Genotype x Environment Interaction, *Morus alba,* biochemical parameters

In spite of India being the second largest producer of silk after China, silk production trends are very much fluctuating. Sericulture includes four major components such as cultivation of host plants for quality leaf production, rearing silkworm for cocoon production, reeling of cocoon to take out silk yarn from cocoons, and fabric production. India produces, all the commercial silk fibers like, mulberry (25344 MT), tasar (2981), eri (6910) and muga (233), more than 70% of the silk come from mulberry silkworm (35468 MT) (Anonymous 2019). *Bombyx mori* silkworm solely feed on *Morus* sps, and mulberry leaf production accounts for more than 60% of the cocoon production cost (Rangaswami *et al*. 1976, Venkatanarasaiah 1992). In India mulberry is grown in a total area of 2,35,001 ha (Anonymous 2019). Therefore, cultivation of mulberry has a significant role to play for the sustainability of sericulture. The nutritional status of mulberry leaves influences the silkworm nutrition as the growth of the silkworm entirely depends upon the levels of proteins, carbohydrates, minerals etc., in the leaves (Anonymous 1975).

To increase the income / return from the mulberry sericulture is either by horizontally i.e. exploring and expanding more and more new areas for mulberry cultivation or by vertically i.e., increasing silk production per unit area of mulberry plantation. Horizontal expansion of area under mulberry plantation is the quicker and easier option provided suitable additional land is available or to explore the new areas (affected with alkali, saline and acidic soil), which are apparently not suited for growing agricultural crops.

Alkali soils are the salt affected soils with pH of more than 8.5, electrical conductivity (EC) of saturated extract of less than 4 mmhos/cm^2, exchangeable sodium percentage (ESP) of more than 15 and Sodium Adsorption Ratio (SAR) more than 30% (Richards 1954). Alkali soils are normally low in nitrogen, medium to high in phosphorous and high in potassium contents, for micro-nutrients contents, low in Zinc, Iron, Manganese, Copper and high in Boron and Molybdenum compared to normal fertile soils (Bhumbla and Dhingra 1964). These alkali soils could be effectively utilized either by reclamation or by growing alkali tolerant genotypes. Reclamation of alkali soils involves replacing excess exchangeable sodium with calcium supplied either through outside source or mobilising precipitated calcium carbonate present in soil. For this purpose, gypsum (direct sources), pyrites, sulphur, acid (indirect sources) and pressmud, green manure and farmyard manure (organic

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matters) are used (Somani and Totawat 1993, Haq *et al.* 2001).

Utilization of these alkali affected soil by identifying the genotypes which must be tolerant to alkalinity. Correlation of biochemical and micronutrient status contributing to leaf yield is of great importance for indirect selection of genotypes for higher leaf yield in mulberry. Path coefficient analysis helps partitioning the correlation coefficient into its direct and indirect effects which permit the breeders to select desired genetic characteristics according to their participation. Genotype × Environment Interaction (GEI) are of major importance, because they provide information about the effect of different environments on cultivar performance (Moldovan *et al.* 2000). The primary objective of the study was to critically assess the inter-varietal genetic variability and its exploitation for improving salt tolerance by screening them in salt affected soils, correlate biochemical and micronutrient content with production of quality mulberry leaves by economic utilization of reclaimed problematic soils.

MATERIALS AND METHODS

The study conducted at black cotton soils of a field unit of Central Sericulture Research and Training Institute, Central Silk Board, Mysuru, with a pH range 9.3 - 9.5, EC range of 0.32 to 0.84 mmhos/cm, Exchangeable Sodium Percentage (ESP) of 42 and Sodium Adsorption Ratio of 30, clearly indicating that the experimental site is a typical alkali soil. The portion of alkali affected area used as unreclaimed alkali soil.

Alkali soil reclaimated with inorganic amendment i.e. gypsum (purity of 70-80% and particle size of > 2 mm) with sulphur was used at 8 MT/ha and 1 MT/ha respectively and with organic amendment i.e. pressmud contains relatively high soluble calcium (from sugar factory employing sulphitation process), was used at 50 MT/ha. Soil after reclaiming with inorganic/ organic amendments were mixed up when soil moisture level was optimum to 10 cm depth in experimental plots. For mixing, shallow ploughing with country plough was carried followed by planking before the onset of monsoon. This was followed by sufficient irrigation to achieve a stand of 5-7 cm water on the soil surface for at least 15 days. In between, puddling was practiced to mix the amendments thoroughly in the soil for effective reclamation. After 15 days, excess water was drained out of the experimental plot through separate channels, plots were irrigated and the water drained out so as to remove excess salts and this process was repeated for effective reclamation. The surface of the soil was allowed to dry completely. Then the land was prepared with proper leveling with little or no slope along the width to facilitate movement of water along the length in a uniform sheet with desired depth of application. Chemical properties of soil samples were analyzed following the method suggested by Jackson (1973) before reclamation and periodically after reclamation with inorganic/ organic amendments. Average pH of the experimental site decreased in soils reclaimed with inorganic (8.3) and organic amendments (7.9) respectively. Average Electric conductivity (EC) of unreclaimed alkali soils was 0.58 mmhos/cm. In case of soil reclaimed with inorganic and organic amendments, the EC was 0.63 and 0.40 mmhos/cm, respectively. ESP was low in soils reclaimed with inorganic amendments (12%), organic amendments (18.6%) in compare with unreclaimed alkali soil (42%). SAR was minimum in soils reclaimed with inorganic amendments (8%) followed by soils reclaimed with organic amendments (14%) compare to unreclaimed alkaline soils (30%).

Five mulberry genotypes relatively tolerant under alkali soil i.e. AR-12, AR-14, AR-10, AR-08 and AR-29 and two improved checks i.e. V1, S34 and one local check were used in the experiment. 64 plants were maintained per genotype and replication in the net plot. Each net plot/ replication was surrounded by a row of border plants. Three experiments were maintained separately and each of the experiment was conducted following randomized block design with three replications. The plantation was established in the field during monsoon season by planting six month old saplings with 0.9 m × 0.9 m spacing. All regular intercultural operations were attended as per the recommended package of practices.

After an initial period of establishment of one year, the plants were pruned at a stump height of 30 cm from the ground level. After pruning and digging, farmyard manure was applied at 20 MT/ha/year in two split doses and thoroughly mixed with the soil by ploughing. The fertilizer schedule followed was 300:120:120 kg of NPK/ha/year in five split doses of 60:60:60 kg NPK/ha after I and III crop and 60 kg nitrogen/ha after II, IV and V crops. Five leaf harvests were made in each year by leaf plucking method. The genotypes were evaluated for biochemical content (total protein content, total carbohydrate content, mineral content, reducing sugar content), micronutrient content (iron, zinc, copper) and leaf yield.

Phenotypic and genotypic correlation co-efficient between two characters were worked out by variance-covariance analysis separately for different amendment treatments as per the method followed by Al-Jibouri *et al.* (1958) using the formula:

$$\text{Correlation Coefficient (r)} = \frac{бxy}{\sqrt{б2x.\ б2y}}$$

Where, xy is the covariance of the characters, x and y, while $б^2x$ and $б^2y$ are the variance of characters x and y, respectively. Considering phenotypic (бpi and бpipj) and genotypic values ($б^2gi$ and бgigj), phenotypic and genotypic correlation were worked out, respectively.

As the leaf yield is the end product for the evaluation study, path analysis was performed separately for different treatments regarding the yield character of the resultant and other significant parameters as casual agents. The path co-efficient analysis was done at genotypic level following Dewey and Lu (1959) using characters. A path co-efficient is simply a standardized partial regression co-efficient and is attained by the simultaneous solution of the equations, which express the basic relationship between correlations and path co-efficient. Path co-efficient analysis is done separately for all the treatments viz. unreclaimed alkali soil,

soil reclaimed with inorganic amendments and organic amendments.

RESULTS AND DISCUSSION

Correlation, path analysis, analysis of variance and stability analysis for genotype, parameters and their interactions under alkali soil, soil reclaimed with inorganic and organic amendment conditions (different environments) was performed and are presented.

Correlation studies

The correlations for different characters viz. biochemical, micronutrient parameters and leaf yield were computed separately for the three reclamation treatments and presented in (Table 1-3). Analysis of variance among all characters under alkali affected soil, soil reclaimed with inorganic and organic amendment conditions was performed and results are given.

Correlation coefficients of bio-chemical parameters in different mulberry genotypes under unreclaimed alkali soils

Correlation studies of biochemical characters and leaf yield are indicated at (Table 1). At phenotypic level, total proteins was positively and significantly correlated with total carbohydrates (0.891**), minerals (0.830**), reducing sugars (0.963**), iron (0.714**), zinc (0.380**), copper (0.743**) and leaf yield (0.972**). At the genotypic level, more or less same results were obtained. Total carbohydrates was found to be positively and significantly correlated with minerals (0.817**), reducing sugars (0.886**), Zinc (0.852**), Copper (0.859**), and leaf yield (0.937**) and positively correlated with iron (0.679*) at phenotypic and at genotypic level none of the correlation coefficient between total carbohydrate and other parameters was significant. Minerals exhibited the same type of correlations with reducing sugars (0.795**), iron (0.544*), zinc (0.708**), copper (0.575*) and yield (0.886**) at phenotypic level and genotypic level, none of the correlation coefficients was significant. Reducing sugars exhibited significant and high correlation coefficients with iron (0.555*), zinc (0.692*), copper (0.617*), and yield (0.983*) both at phenotypic and genotypic level. In case of iron, the character of high correlation with zinc (0.963**), copper (0.880**) and yield (0.565*) both at phenotypic and genotypic level. Zinc was found to be positive and significantly correlated with copper (0.964**) and yield (0.743**) at both at phenotypic and genotypic level. Copper was found to be positive with yield (0.676*) both at phenotypic and genotypic level. The estimates of phenotypic correlation coefficients were similar in sign but higher in magnitude than the ones observed at genotypic level for all characters.

Table 1 Correlation table of bio-chemical parameters of alkaline tolerant mulberry genotypes under unreclaimed alkaline soils

Parameter	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Yield
Total Proteins		0.891**	0.830**	0.963**	0.714**	0.380**	0.743**	0.972**
Total carbohydrates	0.863**		0.817**	0.886**	0.679*	0.852**	0.859**	0.937**
Minerals	0.807	0.802		0.795**	0.544*	0.708**	0.575*	0.886**
Reducing sugars	0.942	0.866	0.786		0.555*	0.692*	0.617*	0.983**
Iron	0.689	0.643	0.511	0.515**		0.963**	0.880**	0.565*
Zinc	0.797	0.827	0.692	0.664*	0.927		0.964**	0.743**
Copper	0.695	0.834	0.539	0.574	0.808	0.901		0.676*
Yield	0.941	0.904	0.873	0.958**	0.547**	0.727*	0.638	

*Significant at 5%; **Significant at 1%
Phenotypic correlation (lower diagonal)
Genotypic correlation (upper diagonal)

Table 1 Correlation table of bio-chemical parameters of alkaline tolerant mulberry genotypes under soils reclaimed with inorganic amendments

Parameter	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Yield
Total Proteins		0.710**	0.440	0.480	0.209	0.720**	0.153	0.814**
Total carbohydrates	0.599*		0.026	0.656*	0.674*	0.858**	0.735**	0.923**
Minerals	0.349	0.021		-0.254	-0.648	-0.056	-0.271	0.039
Reducing sugars	0.391	0.643*	-0.242		0.632*	0.564*	0.523*	0.689*
Iron	0.232	0.658*	-0.609	0.595*		0.681*	0.652*	0.682*
Zinc	0.567*	0.800**	-0.078	0.521*	0.649*		0.802**	0.726**
Copper	0.141	0.718**	-0.263	0.506*	0.637*	0.768**		0.444
Yield	0.699**	0.886**	0.062	0.657*	0.656*	0.669*	0.421	

*Significant at 5%; **Significant at 1%
Phenotypic correlation (lower diagonal)
Genotypic correlation (upper diagonal)

Correlation coefficients of bio-chemical parameters in different mulberry genotypes under soil reclaimed with inorganic amendments

The correlation of different bio-chemical parameters and leaf yield indicated in (Table 2). Total proteins was significantly and positively correlated with total carbohydrate (0.710**), zinc (0.720**) and yield (0.814**) at phenotypic level. However, the correlation was positive with minerals (0.440), reducing sugars (0.480), iron (0.209), copper (0.153) and at genotypic level, more or less same results were obtained. Total carbohydrates was significantly positively correlated with Zinc (0.858**), copper (0.735**), and yield (0.923**) at phenotypic level and at genotypic level, more or less same results were obtained. Minerals was found to be negatively correlated with reducing sugars (-0.254), iron (-0.648), zinc (-0.056) and positively correlated with yield (0.039), results are same in both phenotypic and genotypic level. Reducing sugars positively correlated with iron (0.632*), zinc (0.564*), copper (0.523*) and yield (0.689*) both at phenotypic and genotypic level. Iron exhibited the same type of positive correlations with zinc (0.681*), copper (0.652*) and yield (0.682*) at both phenotypic and genotypic level. Zinc exhibited significant and high correlation coefficients with copper (0.802**) and yield (0.726**) at phenotypic level and results were same in genotypic level. Copper was found to be correlated with yield at both phenotypic (0.444) and genotypic (0.421) level. Similar to unreclaimed alkali soils, the estimates of phenotypic correlation coefficients were similar in sign but higher in magnitude than the ones observed at genotypic level for all characters.

Correlation coefficients of biochemical parameters in different mulberry genotypes under soil reclaimed with organic amendments

Correlation studies of bio-chemical characters and leaf yield under soil reclaimed with organic amendments are indicated at (Table 3), which are almost similar to the treatment, unreclaimed alkali soil. At phenotypic level, total proteins was positively and significantly correlated with total carbohyrdate (0.924**), minerals (0.746**), copper (0.845**) and yield (0.801**). Total proteins had a low positive correlation with reducing sugars (0.382) and iron (0.517). At the genotypic level, more or less same results were obtained. Total carbohydrate was found to be significantly positive correlated with copper (0.756**) and positively correlated with minerals (0.692*) and yield (0.646*) at phenotypic level and same correlation coefficients were recorded at genotypic level. Correlation coefficients between minerals and other characters were significantly positive both at phenotypic and genotypic level. Reducing sugars exhibited the low, positive correlations with iron (0.535*), copper (0.595*), zinc (0.294) and yield (0.360) both at phenotypic and genotypic level. Iron exhibited significant and high correlation coefficients with copper (0.766**) and positive correlation with zinc (0.650*) and yield (0.660*) both at phenotypic and genotypic level. Zinc highly significantly correlated with copper (0.811*) and yield (0.900**) at phenotypic level. In case of specific copper, high correlation with leaf yield both at phenotypic (0.933**) and genotypic (0.848**) level. The estimates of phenotypic correlation coefficients were similar in sign but higher in magnitude than the ones observed at genotypic level for all characters. These traits seem not prone to environmental fluctuations, which may have diluted the expression of correlations between a character pair at genotypic level.

It has been generally accepted that correlation between different characters represents a coordination of physiological processes, which is often achieved through gene linkages (Mather and Jinks 1971). Knowledge of the strength and type of association is an important pre-requisite for the formulation of breeding strategy. Biochemical content is a complex trait influenced by a more number of other parameters. A knowledge of the association between biochemical parameters and its component traits and also between the component traits helps in improving the efficiency of selection.

Table 3 Correlation table of bio-chemical parameters of alkaline tolerant mulberry genotypes under soils reclaimed with organic amendments

Parameter	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Yield
Total Proteins		0.924**	0.746**	0.382	0.517	0.655*	0.845**	0.801**
Total carbohydrates	0.846*		0.692*	0.182	0.308	0.488	0.756**	0.646*
Minerals	0.637*	0.631*		0.602	0.737**	0.752**	1.007**	0.795**
Reducing sugars	0.357*	0.185	0.584*		0.535*	0.294	0.595*	0.360
Iron	0.481	0.280	0.703**	0.520*		0.650*	0.766**	0.660*
Zinc	0.540*	0.439	0.650*	0.249	0.599*		0.811**	0.900**
Copper	0.702**	0.670*	0.887**	0.523*	0.670**	0.686*		0.933*
Yield	0.756**	0.608*	0.769**	0.357	0.655*	0.828**	0.848**	

*Significant at 5%; **Significant at 1%
Phenotypic correlation (lower diagonal)
Genotypic correlation (upper diagonal)

Above observations get support from the findings of several workers viz. Mishra *et al*. (2001) in wheat, Srivastava *et al*. (2001) in soybean, Mohanty (2001) in Brinjal and kharif onion, Neema and Palanisamy, (2001) and Jogdhande *et al*. (2017) in cowpea, Khan and Sukumar (2001) in napier grass (*Pennsisetum purpureum* K. Schum.)

and Iyanar *et al*. (2001) in sorghum. They observed higher genetic correlation coefficients among different characters than the phenotypic correlation coefficients, while studying the relationship between various traits to biochemical parameters. They opined that this might be due to the masking or modifying effect of the environment in genetic association between characters. They also observed shift in the correlation coefficients of biochemical components with yield as well as component characters and attributed it to the differences in the gene complementation of the linkage blocks.

Path analysis

Direct and indirect effects of different bio-chemical parameters of different mulberry genotypes under different treatments are furnished at (Table 4-6).

Table 4 Genotypic path coefficient analysis - Direct (diagonal underlined) and indirect effects of different bio-chemical parameters on leaf yield under unreclaimed alkali soils

Parameters	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Correlation with yield
Total Proteins	0.302	-0.003	0.214	0.478	-0.193	-0.021	0.196	0.972**
Total carbohydrates	0.269	-0.004	0.211	0.440	-0.184	-0.022	0.226	0.937**
Minerals	0.251	-0.003	0.258	0.394	-0.147	-0.018	0.151	0.886**
Reducing sugars	0.291	-0.003	0.205	0.496	-0.150	-0.018	0.162	0.983**
Iron	0.216	-0.003	0.140	0.275	-0.271	-0.025	0.232	0.565*
Zinc	0.253	-0.003	0.183	0.343	-0.261	-0.026	0.254	0.743**
Copper	0.225	-0.003	0.148	0.306	-0.238	-0.025	0.263	0.676*

Residual: 0.253
*Significant at 5%
**Significant at 1%

Path analysis of bio-chemical parameters in different mulberry genotypes under unreclaimed alkali soils

The path analysis with direct and indirect effects different biochemical parameters and their correlation with leaf yield under unreclaimed alkali soils are indicated at (Table 4). Path analysis revealed the direct effect of total proteins (0.302), minerals (0.258), and reducing sugars (0.496) on leaf yield. In copper the direct effects are low but positive (0.263). The most probable reason for low direct effect of iron appears to be the outcome of its negative indirect influence *via* total carbohydrate (-0.003) and zinc (-0.025).

Table 5 Genotypic path coefficient analysis - Direct (diagonal underlined) and indirect effects of different bio-chemical parameters on leaf yield under soil reclaimed with inorganic amendments (Gypsum @ 8 MT/ha. + Sulphur @ 1MT/ha)

Parameters	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Correlation with yield
Total Proteins	0.001	0.659	0.093	0.060	0.101	-0.016	-0.084	0.814**
Total carbohydrates	0.001	0.929	0.005	0.082	0.326	-0.019	-0.401	0.923**
Minerals	0.001	0.024	0.210	-0.032	-0.314	-0.001	-0.148	0.039
Reducing sugars	0.001	0.609	-0.053	0.124	0.306	-0.012	-0.285	0.689*
Iron	0.000	0.626	-0.136	0.079	0.484	-0.015	-0.356	0.682*
Zinc	0.001	0.797	-0.012	0.070	0.33	-0.022	-0.438	0.726**
Copper	0.000	0.683	-0.057	0.065	0.316	-0.018	-0.546	0.444

Residual: 0.215
*Significant at 5%
**Significant at 1%

Path analysis of bio-chemical parameters in different mulberry genotypes under soil reclaimed with inorganic amendments

The path analysis with direct and indirect effects different bio-chemical parameters and their correlation with leaf yield under soil reclaimed with inorganic amendments are indicated at (Table 5). Total carbohydrate (0.929), reducing sugar (0.124) and iron (0.484) have positively significant direct effect on yield. Total proteins had a low (0.001) and copper (-0.546) and zinc (-0.022) had negative direct effect on leaf yield. Like unreclaimed alkali soil, strong direct effect of reducing sugar (0.0.496) was observed. The association of these characters with yield was also found to be positive and significant indicated the importance of these characters.

Path analysis of bio-chemical parameters in different mulberry genotypes under soil reclaimed with organic amendments

Total proteins (2.923) had a highly positive direct effect on the leaf yield and other parameters have negative indirect effect. Similarly, minerals (2.574) had a positive direct effect on leaf yield and other parameters have negative indirect effect indicated at (Table 6). Total carbohydrate (-2.508), reducing sugars (-0.790), iron (-0.484), zinc (-0.148) and copper (-1.274) were observed.

Table 6 Genotypic path coefficient analysis - Direct (diagonal underlined) and indirect effects of different bio-chemical parameters on leaf yield under soils reclaimed with organic amendments (Pressmud @ 50 MT/ha)

Parameters	Total Proteins	Total carbohydrates	Minerals	Reducing sugars	Iron	Zinc	Copper	Correlation with yield
Total Proteins	2.923	-2.318	1.921	-0.302	-0.250	-0.097	-1.076	0.801**
Total carbohydrates	2.702	-2.508	1.780	-0.144	-0.149	-0.072	-0.963	0.646*
Minerals	2.182	-1.735	2.574	-0.475	-0.357	-0.111	-1.283	0.795**
Reducing sugars	1.117	-0.457	1.549	-0.790	-0.259	-0.043	-0.758	0.360
Iron	1.512	-0.772	1.898	-0.423	-0.484	-0.096	-0.976	0.660*
Zinc	1.916	-1.225	1.937	-0.232	-0.315	-0.148	-1.033	0.900**
Copper	2.470	-1.896	2.593	-0.470	-0.371	-0.120	-1.274	0.933**

Residual: 0.259
*Significant at 5%
**Significant at 1%

Complete information about the complex trait like biochemical contents that is controlled by several other traits either directly or indirectly cannot be given by correlation co-efficient alone. Hence, the path coefficient analysis would be quite useful as it permits the separation of direct effect from indirect relation through other related traits by partitioning genotypic correlation coefficients (Dewey and Lu 1959). Studies related to path coefficient analysis and direct and indirect effect of different traits on biochemical parameters under salt stress and reclaimed soil conditions are not available in mulberry. However, path coefficient studies revealed that total protein, total carbohydrate etc. registered strong positive direct effect on leaf yield, under all the conditions viz. alkali soil without reclamation, soil reclaimed with inorganic amendments and organic amendments. It may also be noticed that maximum indirect effects on leaf yield were exerted by total proteins through minerals and reducing sugars. Thus, from the study it is apparent that improvement in total proteins is the most important while developing a high yielding genotype tolerant to alkali soil (Abarshahr *et al*. 2011, Bhutta *et al*. 2019). In absence of studies on path analysis under salt stress conditions in mulberry, it may be concluded that the total proteins has its maximum control on leaf yield through its direct effect as well as its indirect effect *via* other traits especially minerals and reducing sugars. This may be attributed to reduction in salt concentration at root zone due to lower rates of evaporation from the soil surface. The highest total proteins have been recorded in the genotype AR-14 that has contributed towards higher yield.

Biochemical content of the genotypes

The interaction between different treatments indicated in (Table 7a-7b).

Interaction studies on average total protein content

Interaction between the treatments shows significant difference in total protein content between treatments with maximum protein content in case of soil reclaimed with organic amendments (21.51%) and minimum in case of unreclaimed alkali soil (18.60%). Total protein content was significantly higher in the soils reclaimed with organic or inorganic amendments than the unreclaimed alkali soil. Interaction between mulberry genotypes revealed that only AR-12 (22.20%) had significantly higher total proteins than the improved check, S34 as well as normal check, Local, though all the test genotypes except AR-10 contained significantly higher total protein content than normal check, Local. While studying the interaction between different treatments and genotypes, it was found that with reclamation of the soil, the total proteins increased in all the test genotypes as well as improved and normal checks. Maximum increase was observed in case of soils reclaimed with organic amendments. AR-12 under the treatments, soil reclaimed with organic amendments had the maximum total proteins (23.60%) and AR-10 under unreclaimed alkali soil the minimum (16.60%) among the test genotypes. AR-12 and AR-14 were found to be significantly superior over other test genotypes under the soil reclaimed with organic amendments with no significance difference between them.

Interaction studies on average total carbohydrate content

Total carbohydrate in the soil reclaimed with organic amendments (20.84%) were the highest followed by soil reclaimed with inorganic amendments (20.03%) and unreclaimed alkaline soil (17.93%). With reclamation of the soil, total carbohydrate content increased significantly and it was statistically significant in soils reclaimed with organic amendments as compared to other treatments. While studying the interaction between mulberry genotypes under different treatments, AR-12 was found to have the highest total carbohydrates content (22.07%) and the lowest in AR-08 (18.73%), among the test genotypes. Genotypes, AR-12 (22.07%) followed by AR-14 (21.10%) found to be significantly superior over improved check, S34 and normal check, Local. Treatments and genotypes interaction indicated that the soil reclamation has increased the carbohydrate content in both test genotypes and checks. Among the test genotypes, highest carbohydrate content was recorded in AR-12 under soils reclaimed with organic amendments (23.50%) and minimum in AR-29 (17.50%) under unreclaimed alkali soils. AR-12 was found to be significantly superior over other test genotypes under the soil reclaimed with organic amendments followed by AR-14 under soil reclaimed with inorganic amendments with significance difference between them.

Interaction studies on average mineral content

The interaction between the treatments, significant difference was observed in mineral content between treatments with maximum mineral content in soil reclaimed with organic amendments (14.30%) and minimum in unreclaimed alkali soil (8.69%). Mineral content was significantly higher in the soils reclaimed with organic or inorganic amendments than the unreclaimed alkali soils. Interaction between mulberry genotypes revealed that amongst all test genotypes significantly higher mineral content was recorded in AR-12 (12.38%) and it was minimum in AR-10 (9.30%). However, there was no significant difference in mineral content between AR-12 and the entry, V1. Studies on treatment x genotype interaction indicated that, with reclamation of the soil, the mineral content increased significantly in all the test genotypes as well as improved and normal checks, with maximum increase in case of soils reclaimed with organic amendments. No difference in mineral content was observed between unreclaimed alkali soils and soils reclaimed with inorganic amendments with respect to genotypes, AR-10, AR-08, AR-29 and V1. Only AR-12 under soil reclaimed with organic amendments (18.50%) was found to be significantly superior over other test genotypes under different treatments and minimum mineral content was minimum in case of AR-10 (7.00%) under soil reclaimed with inorganic amendments and unreclaimed alkali soils.

Table 7a Bio-chemical parameters (Average total protein, Average total carbohydrates, Average total mineral, Average reducing sugar content) on dry weight basis (%) of different mulberry genotypes under different treatments

Genotype	Average Protein Content				Average total carbohydrates content				Average total mineral content				Average reducing sugar content			
	UR	SRI	SRO	Average	UR	SRI	SRO	Average	UR	SRI	SRO	Average	UR	SRI	SRO	Average
AR-12	20.000	23.000	23.600	22.200	20.100	22.600	23.500	22.067	8.100	10.533	18.500	12.378	1.620	1.740	1.740	1.700
AR-14	19.600	21.000	23.400	21.333	18.700	22.600	22.000	21.100	6.800	9.667	15.200	10.556	1.540	1.620	1.760	1.640
AR-10	16.600	19.600	19.700	18.633	18.400	19.000	19.000	18.800	7.000	7.000	13.900	9.300	1.400	1.460	1.430	1.430
AR-08	18.700	20.600	20.300	19.867	18.700	18.900	18.600	18.733	9.400	9.400	13.867	10.889	1.360	1.660	1.760	1.593
AR-29	18.200	21.000	20.900	20.033	17.500	20.100	20.133	19.244	11.000	11.000	12.800	11.600	1.210	1.393	1.340	1.314
V1	20.000	21.600	23.000	21.533	17.400	19.600	21.800	19.600	11.400	11.400	14.100	12.300	1.320	1.407	1.500	1.409
S34	18.200	21.700	21.333	20.411	16.633	19.200	21.900	19.244	7.600	11.000	13.100	10.567	1.397	1.410	1.410	1.406
Local	17.467	19.400	19.867	18.911	16.000	18.200	19.767	17.989	8.200	11.367	12.900	10.822	1.320	1.407	1.620	1.449
Average	18.596	20.988	21.513		17.929	20.025	20.838		8.688	10.171	14.296		1.396	1.512	1.570	
C.D. at 5% for:																
Treatment (Reclamation)				0.351				0.258				0.262				0.014
Genotype				0.572				0.419				0.429				0.022
Treatment × Genotype				0.993				0.727				0.743				0.038

UR= Unreclaimed alkali soil, SRI= Soil reclaimed with inorganic amendments (Gypsum @ 8 MT/ha. + Sulphur @ 1MT/ha), SRO= Soil reclaimed with organic amendments (Pressmud @ 50 MT/ha)

Interaction studies on average reducing sugar content

Reducing sugar content was highest in soils reclaimed with organic amendments (1.57%) and minimum in unreclaimed alkali soil (1.40%). With reclamation of the soil, reducing sugar content increased significantly and it was statistically significant in soils reclaimed with organic amendments as compared to other two treatments. Genotypes, AR-12 (1.70%) recorded highest reducing sugar content and minimum in AR-29 (1.31%), while studying the interaction between mulberry genotypes. Genotype AR-12 followed by AR-14 (1.64%) was found to be significantly superior over all the test genotypes, improved check, S34 and normal check, Local. Treatment and genotypic interaction indicated that, reducing sugar content of test genotypes and checks has slightly increased with soil reclamation. Among test genotypes, highest reducing sugar content was recorded in AR-14 and AR-08 (1.76%) under soils reclaimed with organic amendments followed by AR-12 under soils reclaimed with organic and inorganic amendments (1.74%) with no significant difference between them and it was minimum in AR-29 (1.21%) under unreclaimed alkaline soils. AR-14, AR-12 and AR-08 found to be significantly superior over other test genotypes and checks.

Interaction studies on average iron content

Though soil reclaimed with organic amendments (78.87 ppm) followed by soil reclaimed with inorganic amendments (77.65 ppm) were significantly superior over unreclaimed alkali soil (48.53 ppm), there was no difference between them at 5% level of significance. Interaction between mulberry genotypes revealed that AR-12 (87.63 ppm), AR-10 (86.13 ppm) and AR-14 (85.49 ppm) are significantly superior over other test genotypes, improved check, S34 and normal check, Local without any significant difference between them. Minimum iron content was found in AR-29 (58.53 ppm) among test genotypes. However, maximum iron content was recorded in AR-12 (87.63 ppm) followed by AR-10 (86.13 ppm) and AR-14 (85.49 ppm), which were significant over other genotypes. Genotype x treatment interaction indicated that, AR-12 (98.60 ppm) under soil reclaimed with inorganic amendments followed by AR-14 under soil reclaimed with organic amendments (97.07 ppm) and AR-10 under soil reclaimed with inorganic amendments (96.60 ppm) have significantly higher iron content over the other test genotypes and checks under different treatments, without significant difference between them. Iron content was minimum in AR-29 (30.60 ppm) among test genotypes, under unreclaimed alkali soil.

Interaction studies on average zinc content

The interaction between the treatments infer that both the treatments i.e. soil reclaimed with inorganic and organic amendments (88.27 and 89.04 ppm) are significantly superior over unreclaimed alkali soils (32.80 ppm) with respect to Zinc content, with no significant difference between them. While studying the interaction between mulberry genotypes, Zinc content was maximum in genotype AR-12 (87.60 ppm) and AR-14 (78.54 ppm), which was found to be significantly superior over the other test genotypes, improved check, S34 and normal check, Local. Zinc content was minimum in AR-08 (65.02 ppm). Whereas, the interaction between different treatments and genotypes indicated that, AR-12 under both soils reclaimed with organic and inorganic amendments (110.00 and 106.00 ppm) exhibited significantly higher zinc content over the other test genotypes, improved checks, S34 and normal check, Local under different treatments and it was minimum in case of AR-29 (30.80 ppm) under unreclaimed alkali soil.

Table 7b Micronutrient content (Iron, Zinc and Copper in ppm) of different mulberry genotypes under different treatments

Genotype	Iron content				Zinc content				Copper content			
	UR	SRI	SRO	Average	UR	SRI	SRO	Average	UR	SRI	SRO	Average
AR-12	72.300	98.600	92.000	87.633	46.800	106.000	110.000	87.600	26.400	42.100	42.600	37.033
AR-14	68.600	90.800	97.067	85.489	40.300	96.633	98.700	78.544	24.800	46.400	36.400	35.867
AR-10	72.200	96.600	89.600	86.133	40.500	88.800	86.000	71.767	23.267	36.600	29.600	29.822
AR-08	44.800	74.200	76.600	65.200	37.200	77.467	80.400	65.022	24.600	19.733	30.800	25.044
AR-29	30.600	76.600	68.400	58.533	30.800	80.633	99.700	70.378	25.600	26.600	29.600	27.267
V1	48.300	70.100	76.400	64.933	24.900	90.600	88.500	68.000	25.333	30.033	30.800	28.722
S34	31.800	56.467	64.600	50.956	21.500	85.600	69.700	58.933	22.267	28.800	29.600	26.889
Loca;	19.600	57.867	66.300	47.922	20.400	80.400	79.300	60.033	22.400	34.400	26.500	27.767
Average	48.525	77.654	78.871		32.800	88.267	89.038		24.333	33.083	31.988	
C.D. at 5% for:												
Treatment (Reclamation)				1.787				2.100				1.197
Genotype				2.918				3.428				1.955
Treatment × Genotype				5.053				5.936				3.387

UR= Unreclaimed alkali soil, SRI= Soil reclaimed with inorganic amendments (Gypsum @ 8 MT/ha. + Sulphur @ 1MT/ha), SRO= Soil reclaimed with organic amendments (Pressmud @ 50 MT/ha)

Interaction studies on average copper content

Soil reclaimed with inorganic amendments (33.08 ppm) followed by soil reclaimed with organic amendments (31.99 ppm) found to be significantly superior with respect to average copper content. Copper content was lowest in alkali soil without reclamation (24.33 ppm). Interaction between mulberry genotypes revealed that amongst all test genotypes significantly higher copper content was recorded in AR-12 (37.03 ppm) and AR-14 (35.87 ppm), which were significantly superior over other test genotypes, improved check, S34 and normal check, Local, with no significant difference between them. Minimum copper content was recorded in AR-08 (25.04 ppm). The interaction between different treatments and genotypes indicated that, AR-14 (46.40 ppm) under soil reclaimed with inorganic amendments has exhibited significantly higher copper content over the other test genotypes and checks under different treatments. Copper content was minimum in AR-08 (19.73 ppm) under soil reclaimed with inorganic amendments. It was also found that the copper content has increased in most of the test genotypes under the soils reclaimed with inorganic and organic amendments as compared to the unreclaimed alkali soil conditions.

The genotypes x environment interactions are major components of variation, i.e. the relative performances of the genotypes vary from one environment to another (Sarkar *et al*. 1986). Ulker *et al*. (2006) also found differences in grain yields of different wheat genotypes in response to different environmental conditions.

The study also provided way forward to the mulberry breeders who are engaged in developing genotypes tolerant or resistant to alkali soil by producing mulberry leaves with high biochemical content for successful cocoon production.

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