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Performance of different Mulberry /*Morus sp.* / genotypes and their effect on mulberry silkworm, *Bombyx mori (Lepidoptera: Bombycidae)*

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Mulberry silkworms (Lepidoptera: Bombycidae) feed only on mulberry leaves and the performance of mulberry silkworms are influenced by mulberry varieties. The studies were conducted in field and laboratory conditions with the objectives to evaluate the agronomic and their rearing performance of different genotypes of mulberry on silkworms. In the present study, six different mulberry genotypes K-2, S-13, M-4, Nekemte, Jimma and Local check were evaluated in the field and laboratory for agronomic and their effect on mulberry silkworm (Bombyx mori). The treatments were arranged with Randomized Complete Block Design (RCBD) in the field and Completely Randomized Design (CRD) for laboratory experiments in three replications. Significant differences were observed in agronomic and rearing performances of mulberry silkworms. In field, maximum leaf production per plant (371.3 and 373.1), fresh leaf weight (26,503 and 26,333 kg/ha) and dry leaf weight (8027 and 8268 kg/ha) were recorded from S-13 and K-2, respectively. However, minimum fresh leaf weight (9435kg/ha) was recorded from Local genotype. Moreover, there were significant differences in rearing performance of silkworms fed on different genotypes of mulberry. Among different genotypes, silkworms fed on leaf of S-13 and K-2 gave better results such as cocoon weight (1.11g and 1.03g), pupal weight (0.924g and 0.864g), shell weight (0.187g and 0.168g), silk ratio (16.82% and 16.35%), as compared to other genotypes. In general, S-13 and K-2 showed better results in agronomic performances as well as in rearing performance of silkworms for improving silk production as compared to other genotypes. Thus, the result obtained by feeding of S-13 and K-2 genotypes of mulberry contributes for improving the rearing performance of mulberry silkworms. Therefore, these genotypes are recommended for further research and development works of Sericulture in the Country.

Key words: Mulberry genotypes, Agronomic, Mulberry Silkworm and Rearing Performance

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INTRODUCTION

Silkworm *(Bombyx mori L.)* is essentially monophagous insect feeds solely on mulberry leaves *(Morus spp.).* Leaf quality is an important parameter used for evaluation of varieties aimed at selection of superior varieties for rearing performance. Growth and development of silkworm *Bombyx mori L.* is known to vary depending on the quality and quantity of mulberry leaf used as food source, which in turn indicated by commercial characteristics of cocoon crop (Nagaraju, 2002). Mulberry varieties regarded as one of important factors that effect on number of laid eggs, fecundity, hatchability, larval period and weight in silkworms. This variation will lead to various physiological state and cocoon production. Maximum of larval growth and uniform cocoon production determined by mulberry leaves varieties and caused that long silk fiber in silkworm fed (Adolkar et al., 2007).

It also been observed that the growth and development of silkworms and quality of silk cocoon produced are directly influenced by the variety and quality of leaves fed to the worms. Morphological characters of leaves contribute to acceptability by silkworms (Krishnaswami *et al.,* 1970). Gogoi and Goswami (1998), studied genotypes and observed variation in leaf yield in different genotypes.

Hence, selection of mulberry genotypes is an important criterion for better growth and development of silkworm for proper nourishment to obtain better fecundity and higher cocoon productivity (Joshi and Misra, 1982). However, the performance of the mulberry silkworm with regard to mulberry genotype differences has not been identified and documented in Ethiopia. Therefore, this work was to evaluate the agronomic and their rearing performance of different genotypes of mulberry on silkworms for improving silk production and to find out a promising mulberry genotype in respect to economic traits.

MATERIALS AND METHODS

Experiment conducted on field and laboratory, for field it was tested across different Agricultural Research Center (Melkassa, Jimma, Wondogenet, Hawassa) and Alage ATVET College whereas, for the laboratory it was conducted under Melkassa Agricultural Research Center.

About 6 genotypes of mulberry namely, S-13, K-2, M-4, Nekemte, Jimma, and Local check were used as a treatment and evaluated under field and laboratory conditions. The study was carried out under rain fed condition with supplemental irrigation during dry periods. Mulberry cuttings were planted with a spacing of 60 cm within plants and 60 cm between rows on a plot size of 3.6 cm * 3.6 cm. The treatments were arranged with RCBD in three replications in the field.

For laboratory mulberry silkworm was reared on the 6 mulberry genotypes. The silk worm rearing room and equipment's were cleaned, washed and disinfected with 2 % formalin solution at the rate of 800 ml per 10m^2 before the commencement of the experiment (Dayashankar, 1982). This silk worm was reared following cellular techniques starting from brushing till silkworms at larval stage was fed four times a day with tender leaves until III instars and mature leaves until V instars. The grown up worms were picked and left on the mountages for spinning. On the sixth-eighth day of spinning, the cocoons were harvested, counted and weighed (Singh and Benchamin, 2002). The experiment was arranged in Completely Randomized Design (CRD) in three replications. In each replication, 200 worms/tray were used and allowed to complete the larval period to cocoon spinning on the six genotypes.

Data collection

Agronomic parameters like, plant height, leaves production per plant, number of primary and secondary branches, fresh and dry leaf weight, stem thickness, leaf area, internode length incidence and severity were recorded. For the laboratory, rearing variables like larval duration (days), larval body weight (g), hatchability (%), effective rate of rearing (%), cocoon traits like (cocoon and shell weight in grams and silk ratio in percent) and fecundity (number of eggs per female in number) were recorded. The following formulae adopted by Singh and Benchamin (2002) were used:-

$$\text{Hatchability (\%)} = \frac{No. of\ \ normal\ eggs - number\ of\ non\ hatched\ eggs}{No. of\ normal\ eggs} x\ 100$$

$$\text{Silk ratio} = \frac{weight\ of\ shell}{Weight\ of\ fresh\ cocoon} x\ 100$$

$$\text{Effective rate of rearing (ERR)} = \frac{No. of\ larvae\ spinning\ cocoon}{No. of\ larvae\ brushed} x\ 100$$

Data Analysis: The data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (Gomez and Gomez, 1984) (version 9.00, SAS, Institute Inc., Cary, NC, USA). Treatment means were separated using Duncan multiple ratio.

RESULTS AND DISCUSSION

Evaluation of mulberry genotypes in field and its rearing performance in laboratory were carried out. Mulberry silkworms fed with the leaves of different genotypes of mulberry and their response was evaluated. Results showed that in all locations displayed significant (P<0.05) differences for a number of agronomic and yield characters for different mulberry accessions as compared to local check.

The qualitative and quantitative traits of mulberry genotypes can be expressed in terms of their morphological differences such as, plant height, stem thickness and number of branches, internodes and leaf area. Therefore, such differences in mulberry genotypes will lead to different directions of their utilization. Among all treatments, S-13 and K-2 gave significantly (P<0.05) higher yield as compared to local check and other treatments. They gave better and similar results in most of the measured parameters (Table 1).

Plant height, number of primary branches, stem thickness as well as internode length showed statistically significant differences among mulberry genotypes. Highest plant height was recorded from (277.04 cm) from Wondogenet site and the shortest was 194 cm from local mulberry genotype. However, the highest primary branch was from K-2 (21.5) and minimum was recorded from Nekemte (8.2). In addition, long internode length was registered by M-4 (8.3 cm) but the shorter was by S-13 (5.7 cm). Moreover, maximum leaf area was recorded 333 cm^3 but the short one was 144cm^3. In another way, high stem thicker was obtained from local (14.2 cm) but the thinner one was from K-2 (9 cm) (Table 1). During the experimental period, disease particularly leaf spot was becoming serious problem. As a result, disease incidence and severity was recorded. Therefore, significant difference was observed among the genotypes. Thus, highest disease incidence was recorded from Nekemte (64.24 %) at Alage site, but the lowest was recorded from S-13 (8.3 %) at Melkassa site. Similarly, the highest disease severity was recorded from local check (53.8 %) but lowest was recorded from S-13 (10.5 %) (Table 2).

As it can be realized from the results of the present investigation, mulberry genotypes showed wide variation in their quantitative and qualitative traits. Consequently, these differences resulted in significant variation in rearing performance and feeding efficiency of silkworms when leaves of these genotypes were used as a feed material.

There were significant differences (P<0.05) in number of leaf production, fresh and dry leaf weight among treatments in different locations. Maximum fresh leaf weight (26503 kg/ha) and dry leaf weight (8268 kg/ha) were recorded. However, the least fresh (9435 kg/ha) and dry leaf weight (2453 kg/ha) was recorded in local accession from Alage site, respectively (Table 3).

Evaluation of any crop is a continuous process to evolve new varieties suitable for specific zones for commercial utilization. The present scenario of sericulture industry demands new varieties suitable for various agro climatic conditions. Suitable parent material needs to be identified from large number of germplasm accessions for the purpose. Moreover, estimates of genetic diversity and relationship between various collections from diverse origin help in efficient management and utilization of germplasm (Rabbani *et al.,* 1988). Several studies have already highlighted the variability of mulberry germplasm and association of different agronomical traits was also studied in detail (Tikader and Rao, 2002a).

Studies on nutritional ecology of an insect are very important for its commercial exploitation (Slansky and Scriber, 1985). The suitability of host is determined through estimation of rate of ingestion, digestibility, conversion efficiency of food and growth rate of the animal (Englemann, 1966). Nutritive value of mulberry *(Morus sp.)* leaf is a key factor besides environment and technology adoption for better growth and development of the silkworms and cocoon production. It is a confirmed fact that, leaf quality differs among mulberry varieties which in turn responsible for the difference in silkworm rearing performances (Bongale *et al.,* 1997). Leaves of superior quality enhance the chances of good cocoon crop (Ravikumar, 1988).

When genotypes perform consistently across locations, breeders should able to effectively evaluate germplasm with a minimum cost in a few locations for ultimate use of the resulting varieties across wider geographic areas (Gemechu, 2012). However, with high genotype by location interaction effects, genotypes selected for superior performance under defined environmental conditions (Ceccareelli, 1997). Therefore, it could be implicated that selection of better performing genotypes at one location may not enable the identification of genotypes that can repeat nearly the same performances at another location.

The results indicated that mulberry genotypes of S-13, K-2, M-4, Nekemte, Jimma, and and local check resulted significant variation in rearing performances of the worms. Insects do vary in efficiency of conversion of digested food due to the varied level of nutrients intake, quality of the food and total biochemical components of the leaf supplied to the insects (Krishnaswami *et al.,* 1970). Among different genotypes of mulberry, silkworms fed on leaf of S13 and K2 gave better results. In accordance to yield, maximum cocoon weight was recorded in those larvae which were fed on the leaves of S-13 (1.11g) and followed by that of K-2 (1.03g). The minimum cocoon weight (0.866 g) was recorded in local check. Similarly, the highest pupal weight was recorded from S-13 and K-2 (0.924g and 0.865g) respectively and the lowest was from local check (0.73 g) (Table 4).

Shell weight of cocoon revealed significant variation when fed with the different mulberry accession. Mulberry genotypes of S13 and K2 revealed significantly higher shell weight (0.187g and 0.168g) respectively as

Table 1. Means for plant height (cm) and number of leaf per plant during the production seasons of 2013/2014 to 2016/2017 at harvesting stage of mulberry accessions grown across locations

Treatment	Plant height and number of leaf per plant at harvest respectively									
	Melkassa		Jimma		Wondogenet		Hawassa		Alage	
	PH	NL	PH	NL	PH	NL	PH	NL	PH	NL
Nekemte	202.6a	224.9cd	242.4a	206.56 b	242.41a	142.22ab	238.89a	126.72 b	220.5a	138.93 bc
Jimma	225.6a	278.4bc	276.48a	165.29b	276.48 a	139.45b	243.11a	171.46 ab	222.2 a	123.91c
M-4	202.7a	167.7d	277.04 a	208.85b	277.04 a	140.85 ab	254.72 a	182.94ab	229.12 a	166.24abc
K-2	211.3a	303.6b	260.89a	373.11 a	260.89a	188.44ab	256.94 a	209.61a	203b	232.77ab
S-13	227a	371.3a	219.08a	340.78 a	219.08a	177.82ab	226.50 a	227.89 a	218ab	272.07a
local	194a	217cd	269.93a	203.11 b	269.93 a	144.85 ab	242.22 a	158.45ab	216ab	136.14 bc
CV	**10.7**	**13.8**	**19.9**	**17.6**	**19.90358**	**17.15869**	**14.4**	**21.7**	**4.2**	**32.91**
LSD	**41**	**65.3**	**93.29**	**80.1**	**93.29**	**48.574**	**63.8**	**70.9**	**16.64**	**106.8**

Means within the same column with a common letter are not significantly different (P<0.05), PH= plant height (cm), NL= Number of leaves per plant

Table 2. Means for primary and secondary branches production seasons of 2013/2014 to 2016/2017 at harvesting stage of mulberry accessions grown across locations

Treatment	Primary and Secondary branches									
	Melkassa		Jimma		Wondogenet		Hawassa		Alage	
	1ry	2ry	1ry	2ry	1ry	2ry	1ry	2ry	1ry	2ry
Nekemte	8.2b	13.6a	11.667bc	6.147a	11.667	6.147a	13.460 a	4.500ab	12.8b	8.2b
Jimma	8.8b	14a	8.703 bc	4.997 ab	8.703	4.997 ab	14.367a	5.553 ab	12.1b	9 b
M-4	8.3b	1.5c	8.220c	1.443 c	8.220	1.443c	11.780 a	1.943bc	17.3ab	7.5 b
K-2	13.6a	10.7ab	15.853a	5.740a	15.853	5.740 a	16.613 a	4.387abc	21.5 a	11.8 a
S-13	14.9a	5.4bc	11.960 b	2.553 bc	11.960	2.553 bc	14.110a	0.667 c	16.7ab	4.7c
Local	8.1a	11.8a	9.780 b	4.667ab	9.780	4.667 ab	12.187a	5.997a	11.7b	7.7 b
CV	**9.5**	**31.8**	**17.68165**	**34.11395**	**17.68165**	**34.11395**	**26.12270**	**54.42767**	**25.5**	**15.2**
LSD	**1.79**	**5.5**	**3.5483**	**2.6425**	**3.5483**	**2.6425**	**6.5359**	**3.8034**	**7**	**2.3**

Means within the same column with a common letter are not significantly different (P<0.05), PH= plant height (cm), NL= Number of leaves per plant, 1ry=primary branches, 2ry= secondary branches

Table 3: Means for fresh and dry leaf weight (kg/ha/year) at harvesting stage of mulberry accessions grown across locations

Treatment	Fresh and Dry leaf weight (kg/ha) at harvesting stage, respectively									
	Melkassa		Jimma		Wondogenet		Hawassa		Alage	
	FLW	DLW	FLW	DLW	FLW	DLW	FLW	DLW	FLW	DLW
Nekemte	14645b	4592b	13199d	4272.6b	12478b	4822b	11535 c	4055.6ab	11116b	2890.1 b
Jimma	17846b	5168ab	13793 cd	4375.5 b	13513b	4736b	12162c	4216.1 ab	12017b	3124.4b
M4	16586b	4800b	19808bc	5083.3 b	19688ab	7044ab	14640bc	4726.9ab	11889b	3091.1 b
K-2	24419a	7162ab	26333a	7698.6 a	26330a	8268a	21063a	6236.6 a	20597a	5355.3 a
S-13	26503a	8027a	24053ab	6728.4 a	20865ab	6232ab	18830ab	5831.8b	18975a	4933.6 a
Local	13046b	6245ab	13551d	4152.3b	14321b	4651b	10548c	3520.1 b	9435b	2453.1 b
CV	**169**	**28**	**17.98570**	**14.61082**	**26.44402**	**23.79**	**22.40623**	**25.5**	**15.9**	**15.9**
LSD	**5820**	**3089.5**	**6039**	**1431.4**	**8595.2**	**2578.6**	**6031.5**	**2207.8**	**4051.2**	**1053.3**

Means within the same column with a common letter are not significantly different (P<0.05), FLW= Fresh leaf weight, DLW= dry leaf weight, TFLWHA= total fresh leave per hectar, TDLWPP= total fresh leave weight per plant

Table 4. Means for stem thickness, leaf area and Internode length during the production seasons of 2013/2014 to 2016/2017 at harvesting stage of mulberry accessions grown across locations

Treatment	stem thickness, leaf area and Internode length at harvesting stage, respectively														
	Melkassa			Jimma			Wondogenet			Hawassa			Alage		
	ST	LA	IL	ST	LA	IL	ST	LA	IL	ST	LA	IL	ST	LA	IL
Nekemte	9.8	258	6.3ab	13	276ab	6.5	13.3	276ab	6.5	11	144c	6.4	11.6	147.55b	6.7
Jimma	9.4	258	5.9ab	13.9	333 a	6.5	13.8	333 a	6.5	11	220ab	6.5	11.8	167.69b	6.5
M-4	9.2	267	5.5b	13.6	326a	5.9	13.6	326 a	5.99	13	229 a	7.9	12.98	242.67 a	8.3
K2	9	241	6.4a	12.9	248ab	6.4	12.9	248 ab	6.4	13	168 abc	6.4	13.3	169.53b	6.7
S13	10.6	194	5.7ab	11.1	205 b	6.7	11.1	205 b	6.7	11	139c	6.3	11.49	138.89b	6.7
Local	9.4	225	7.28	14.2	313ab	6.9	14.2	313 ab	6.86	12	150 bc	7.7	12.53	150.22b	7.9
CV	**11.4**	**17**	**0.8**	**21.0**	**21**	**13.6**	**21**	**21**	**13.64**	**23**	**22**	**16.5**	**21.7**	**22.97**	**18.3**
LSD	**1.94**	**74**	**0.73**	**5**	**111**	**1.6**	**5**	**110.5**	**1.6**	**5**	**70.5**	**2.1**	**4.86**	**70.82**	**2.36**

Means within the same column with a common letter are not significantly different (P<0.05), ST= stem thickness, LA= leaf area, IL= internode length

Table 5: Means for Incidence (%) and Severity (%) at harvesting stage of mulberry accessions grown across locations

Treatment	Incidence (%) and Severity (%) at harvesting stage, respectively									
	Melkassa		Jimma		Wondogenet		Hawassa		Alage	
	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity
Nekemte	23.24a	37.4a	28.607 ab	29.073 bc	28.607ab	29.073bc	21.737 a	22.667ab	64.243a	51.447a
Jimma	22.23ab	33.7a	26.770 abc	37.150ab	26.770abc	37.15ab	18.253 a	18.167 bc	56.6ab	49.163a
M4	16.9ab	18b	21.037 bc	16.813 d	21.037 bc	16.813d	20.370a	14.017 c	25.5d	30.280b
K2	**10.6ab**	**17b**	**18.620 c**	**23.923cd**	**18.620 c**	**23.923cd**	**15.133 a**	**15.777 c**	**38.887c**	**26.833b**
S13	**8.3b**	**10.5b**	**20.230 bc**	**17.967 d**	**20.230 bc**	**17.967 d**	**17.983 a**	**19.643 abc**	**27.23d**	**30.663b**
Local	21.4ab	36.7a	30.533 a	40.627 a	30.533 a	40.627 a	19.640 a	25.473a	47.853 bc	53.833a
CV	**45.3**	**20.4**	20.33731	21.94813	20.33731	21.94813	42.90386	17.93634	14.38443	25.11686
LSD	**14**	**9.5**	8.9906	11.017	**8.9906**	**11.017**	14.715	6.2947	11.356	18.447

Means within the same column with a common letter are not significantly different (P<0.05),

Table 6: - Performance of bivoltine mulberry silkworm strain fed on different mulberry varieties

Treatment	Hatching percent	Larval duration (days)	Larval weight (gram)	Cocoon weight (gram)	Pupal weight (gram)	Shell weight (gram)	Silk ratio (%)	Fecundity	ERR (%)
K-2	70.7033b	32.0000c	2.17700b	1.03000b	0.86467b	0.16833ab	16.350	279.933c	75.56667c
S-13	70.0000b	31.5000c	2.53033a	1.11167a	0.92433a	0.18700a	16.820	305.467a	81.50000a
M-4	75.3300a	33.0000b	2.17100b	1.01333b	0.83000b	0.16333ab	16.123	289.867b	77.00000b
Nekemte	65.4300c	34.0000a	2.19200b	1.00133	0.84300b	0.15867bc	15.890	270.533c	73.67000e
Jimma	62.0200c	34.0000a	2.23300b	1.00600b	0.84467b	0.16133bc	16.053	278.200c	74.02000d
Local	65.0000c	34.0033a	2.00633c	0.86567c	0.73000c	0.13600c	14.073	259.533d	68.83333f
SE	1.07154353	0.25757687	0.04213927	0.01868696	0.01463906	0.00461825	0.32462796	3.67579869	0.92527588
CV (%)	0.637592	1.123689	4.154814	3.194023	2.602669	8.825915	9.785895	1.973116	0.157055
Pr	<.0001	<.0001	0.0005	<.0001	<.0001	0.0238	0.9654	<.0001	<.0001

Means within the same column with a common letter are not significantly different ($P<0.05$), B: Hap= hatching percentage, LaD= larval duration (HR), Larw =larval weight, CoW= cocoon weight, Shw =shell weight, SiR= silk ratio, fecund= fecundity, ERR =effective rate of rearing;

compared to local check and other treatments however, the least shell weight (0.136g) was recorded from local check. In parallel with shell weight, silk ratio was found significantly highest in S-13 and K-2 (16.82 % and 16.35 %) respectively but the lowest in local check (14.07 %) (Table 5).

Hatching of silkworm egg showed wide significant variation fed on different mulberry genotypes from 62 % to 75.33 %. The maximum hatching was recorded in M4 (75.33 %) closely followed by K-2 (70.7 %), but lower hatching percent was obtained from Jimma (62%). Larval duration in days was recorded when the beginning is day and hour of larval brushing and the end is day and hour when the feeding is stopped and larvae mounted. Significant differences were observed in hatching percentage among treatments. Longer larval durations (34 days) were recorded in the worms fed on Nekemte, Jimma and Local genotype whilst, S-13 and K-2 genotype showed shorter larval duration (31.5 and 32 days) respectively, as compared to other treatments. Silkworm fed on S13 recorded significantly higher fecundity (305.5) followed by M-4 (289.9). The lowest fecundity was recorded from local check (259.5). Effective rate of rearing (ERR) has also revealed significant difference when mulberry silkworm fed on different mulberry genotypes. Mulberry silkworm fed on S-13 (81.5 %) recorded higher ERR closely followed by M-4 (77%) and K-2 (75.6 %). The least ERR was obtained from local check (68.83 %) (Table 6).

The silkworm is an of economic insect used for silk production and Sericulture or silkworm rearing depends on mulberry leaves as the sole natural food of the silkworm *Bombyx mori L.,* the quality of the mulberry leaves has a direct bearing on the normal growth of the larvae and the quality of the cocoon (Adolkar, 2007). The composition of mulberry leaves plays an important role in the growth and development of silkworms and other traits important to the economic production of these animals (Legay, 1958). Significant seasonal variations occur in the nutritional value and composition of mulberry leaves depending on factors such as the weather, pests and diseases as well as agricultural practices such as fertilization, irrigation and other current practices (Ito, 1978). This variation impacts both qualitatively and quantitatively upon the silkworm cocoon production. Weakness of nutritive value of mulberry leaves will lead to significant decrease of silk production (Legay, 1958). The study by Rajesh *et al.,*(2010) on the increase of larval weight, cocoon and pupal weight and silk ratio exhibited by the silkworm fed on leaf was explained due to the higher rate of food ingestion, food assimilation and respiratory activity. The involvement of these factors in increasing the larval body substance has been reported by Stockner (1971). In general, S-13 and K-2 showed better results in agronomic performances in the field and also gave better results in rearing performance of silkworms in the laboratory. Mulberry varieties regarded as one of important factors that affects on number of laid eggs, fecundity, hatchability, larval period and weight in local strains and obtained in silkworms. This variation will lead to various physiological state and cocoon production (Das and Ghvan, 1990).

CONCLUSION AND RECOMMENDATION

The present study reveals that mulberry varieties have strong influence on mulberry silkworm rearing performance. The genotypes S-13 and K-2 performed best results in most important agronomic parameters in the field and rearing performance in the laboratory conditions as compared to other accessions. Since mulberry varieties have strong influence on mulberry silkworm rearing performance thus, selection of the varieties for rearing mulberry silkworms is very important in order to get better yield. Therefore, based on agronomic and laboratory results S-13 and K-2 were found to be the best promising mulberry variety for rearing of mulberry silkworm and will be recommended for mulberry silkworm research and development efforts in future.

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