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Estimation of Moisture content and Moisture Retention Capacity of elite Mulberry Varieties during Chawki and Late age rearing (Spring, 2019) under Sub-tropical condition of Jammu (J & K)

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ABSTRACT
The present investigation was carryout during spring (2019), the data revealed that, maximum moisture content recorded in Vishala (76.83%), C-2038 (77.24%) and C-2038 (76.93%) and observed significant differences among all the varieties for chawki, late age and overall mean respectively during complete rearing. For MRC at 6 h high retention was observed in G-4 (95.79%), Vishala (96.16 %) and C-2038 & G-4 (95.73%) and all the varieties showed statistically non-significant for chawki stage, late age and overall mean respectively. All the varieties showed significant differences among each other for MRC during chawki stage at 12 h, C-2038 retained maximum moisture retention (92.71%), during late age C-2038 retained maximum moisture (92.09%) and showed non-significant among them. For overall mean, there are statistical differences among all the varieties for MRC at 12 h, C-2038 retained maximum moisture content (92.40%). During chawki stage, higher moisture was retained C-2038 (89.17%) and significant among them, higher moisture was retained in variety C-2038 (86.34%) during late age rearing and showed non significant among all the varieties. For overall mean, higher moisture was retained in variety C-2038 (87.76%) and all the varieties showed significant differences statistically at 24 h for overall mean. During chawki rearing according to the evaluation index (E.I) for MC and MRC, the mulberry varieties were shortlisted as C-2038 having E.I value 59.30 followed by G-4 (54.82) respectively. During late age rearing, C-2038 having E.I value 58.75 followed by Vishala (53.32) and for overall mean, the mulberry varieties were shortlisted as C-2038 having E.I value 61.79 followed by G-4 (51.76) and S-1635 (51.33) respectively.
Key words: Moisture content, Moisture retention capacity, Varieties, Chawki, Late age

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INTRODUCTION

About 92.20 *per cent* of the silk produced in the world is obtained from mulberry silkworm, *Bombyx mori* L. reared 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 [58] and [7]. Growth and development of silkworm, *B. 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 [38] [54] [4] and [35]. Superiority of different mulberry varieties used as food for silkworm larvae greatly affects the economy of sericulture industry [9]. Nutritive value of mulberry (*Morus* spp.) leaf is a key factor besides environment and technology adoption for better growth and development of the silkworms and cocoon production [42]. It is a confirmed fact that, leaf quality differs among mulberry varieties which in turn responsible for the difference in silkworm rearing performances [7]. Leaves of superior quality enhance the chances of good cocoon crop [43].

Quality of mulberry leaf was highly influenced by varieties, cultivation practices, preservation techniques, age and position of leaf and leaf quality was determined based on moisture content. Higher moisture content of mulberry leaves has a direct effect on growth and development of silkworm by favouring the ingestion, digestion and assimilation of nutrients. Mulberry leaves containing more water, total sugar and soluble carbohydrate and less mineral are best relished by silkworms. Nutritive requirement of silkworm

larvae vary with the maturity of leaves fed. Chawki silkworms required leaves of high moisture content as it is easy to digest and late age silkworms required mature leaves with less moisture content as late age silkworms have the strength to digest mature leaves. On the other hand too much mature leaves do not contain sufficient biochemical contents and moisture content is not suitable to feed silkworms.

Better the quality of mulberry leaves greater are the possibilities of obtaining good cocoon crops. Since the production of good quality cocoons depends on providing good quality leaves to silkworm, the development of superior quality leaf has become one of the prime objectives in mulberry breeding programme. Different quality traits such as leaf moisture content, proteins, carbohydrates, nitrogen, amino acids and chlorophyll are responsible for leaf quality [6]. About 70 *per cent* protein of Silk is directly derived from mulberry leaves. The nutrient contents of mulberry leaves have a great affects on the growth of silkworm, cocoon crop and finally on raw-silk-yield. Worm health and cocoon characters are highly affected by quality and quantity of food [23] and [44]. The efficiency of converting the ingested and digested food into body, cocoon and cocoon shell varies among the silkworm breeds under the influence of mulberry varieties and season was reported [1].

MATERIAL AND METHODS

The present investigation was taken up on mulberry bush raised under sub-tropical conditions of Jammu (J & K) during 2019-2020 at Regional Sericultural Research Station (RSRS), Miran Sahib, Jammu. It is winter capital of J & K state of India. The Jammu city is a hilly area and is surrounded by snowcapped mountains. The Jammu city is located at an altitude of 327 m Above Mean Sea Level (AMSL) and has a latitude and longitude of 32.73 North and 74.87 East. Jammu city is also surrounded by Shivalik range & Trikuta range. It is 600 Km from New Delhi, the capital of India. Most of the annual rain fall in the district is observed between the month of June to September. Jammu the Northern most part of India experiences a sub-tropical climate that features to major seasons, a very hot summer and a chilly winter. During the summer month, the temperature in Jammu climb to 45° C, although the season gets a great level of rain fall. It hardly helps to reduce the heat. On the other hand winter remains chilly. Temperature often drops due to 4°C and it fluctuates between 14-18°C. Mulberry varieties namely S-146, S-1635, G-4, Vishala and C-2038, were taken up for the study. The experiment was laid out in a Randomized Block Design (RBD) with three replications for each variety. Plants were raised at 3' x 2' spacing was kept uniform.

Moisture Content (MC) and Moisture Retention Capacity (MRC)

The moisture content of the leaf was determined on dry weight basis. One hundred fresh leaves, comprising of tender, medium and coarse leaves were harvested early in the morning and weighed immediately. They were then kept at room temperature and weighed again after 06, 12 and 24 hours [37]. The leaves were then dried in hot air oven at 60°C for 48 hours. Later, the dry weight was recorded and the moisture content and moisture retention capacity calculated as per the following formulae:

$$\text{Moisture content (\%)} = \frac{\text{(Fresh weight - Dry weight)}}{\text{Fresh weight}} \times 100$$

$$\text{Moisture retention} = \frac{\text{(Weight after 6 hrs - Dry weight)}}{\text{Capacity after 6 hrs}} \times 100$$

$$\text{(Fresh weight - Dry weight)}$$

$$\text{Moisture retention} = \frac{\text{(Weight after 12 hrs - Dry weight)}}{\text{Capacity after 12 hrs}} \times 100$$

$$\text{(Fresh weight - Dry weight)}$$

$$\text{Moisture retention} = \frac{\text{(Weight after 24 hrs - Dry weight)}}{\text{Capacity after 12 hrs}} \times 100$$

$$\text{(Fresh weight - Dry weight)}$$

Three observations per treatment per replication were recorded and an average was calculated. Evaluation Index will be workout as per the procedure suggested and same index used for moisture content and moisture retention capacity [32].

$$\text{Evaluation Index} = \frac{A - B}{C} \times 10 + 50$$

Where,
A = Value obtained for a particular trait for the varieties,
B = Mean value of a particular trait for all the varieties,
C = Standard deviation of a trait of all the varieties
10 = Standard Unit
50 = Fixed value
The index values for each trait will be pooled together and mean (evaluation index) would be calculated for each varieties. The varieties with index value > 50 are to be considered to be better performers which were otherwise, the resultant of index measurement made on important traits covering various economic parameters.

RESULTS AND DISCUSSION

High leaf moisture content and moisture retention capacity of the mulberry genotypes have a positive influence on the growth and development of silkworm. For successful rearing, the maintenance/retention of sufficient moisture content in the leaves for prolonged periods is of immense importance [27] [15] & [31]. Different genotypes are said to influence the leaf moisture content and its retention in harvested leaf. Besides, environmental factors, leaf anatomical parameters like stomatal size, stomatal frequency, mesophyll tissue, cuticle thickness and leaf thickness also influence the moisture content of the leaf and its retention capacity. Further, stated that silkworm *B. mori* being monophagus insect, consumes only mulberry leaves [14] & [57].

The nutritional quality of the leaves play a important role in silkworm rearing, higher moisture content is known to increase the amount of ingestion and digestability of silkworm because moisture act as olfactory and gustatory stimulant [56] & [41]. The study was carried out on the leaf yield and bioassay of mulberry varieties through silkworm rearing which clearly indicated varietal difference in all parameters regulating leaf quality [19] [21] & [20]. The effect of mulberry varieties on the growth and economic characters of silkworm. These studies showed that quality of mulberry leaf is one of the major deciding factors for healthy growth of silkworms and success of cocoon crops. The quality of leaf is influenced by a number of factors such as variety, cultural practices, incidence of pest and diseases, method of harvesting and preservation of leaves [53] [36] [26] [24] and [46].

The varieties which were superior with respect to yield and growth parameters were selected to assess the moisture content and moisture retention capacity at 6 h, 12 h and 24 h during spring (2019) for chawki and late age rearing time. The results of five different elite mulberry varieties *viz*., S-146, S-1635, G-4, Vishala and C-2038 for moisture content and moisture retention capacity at 45 days after pruning (DAP) are as follows.

Leaf moisture content (%)

Vishala recorded maximum moisture content (76.83 %) followed by C - 2038 (76.61 %), G - 4 (75.40 %), S -146 (75.20 %), whereas minimum moisture content was noticed in S - 1635 (74.64 %). All the varieties showing significant differences among each other for moisture content recorded during chawki stage of silkworm rearing (Table 1). During late age of silkworm rearing, all the varieties showed significant differences statistically among each other for moisture content, the variety C-2038 recorded maximum moisture content (77.24 %) followed by S - 1635 (76.02 %), Vishala (74.76 %) and S-146 (74.47 %), whereas minimum moisture content was noticed in G-4 (72.98 %) (Table 2). The overall mean revealed that, C-2038 recorded maximum moisture content (76.93 %) followed by Vishala (75.80 %), S-1635 (75.33 %) and S-146 (74.84 %), whereas minimum moisture content was noticed in G-4 (74.19 %) and observed significant differences among all the varieties with respect to moisture content for overall mean during complete rearing (Table 3).

The availability of moisture content in the leaves enhances the feeding efficiency of larvae which in turn increases the growth rate [56] & [41]. The leaf moisture content may serve as one of the criteria in estimating the leaf quality [40]. The wide range of variation for moisture content in tender (61.58 to 74.17 %), medium (58.48 to 70.35%) and coarse mulberry leaves (53.36 to 69.00 %) has been recorded [2].

The low moisture adversely affects the growth and development of silkworm [47]. Demonstrated that moisture loss can be minimized over a certain period of time using wet gunny cloth or alkathene sheet [22].

There is wide range of variation in eight varieties of mulberry for moisture content (63.67 to 70.60 %) and total sugars (8.64 to 15.58%) [54]. The study on 23 elite mulberry genotypes and observed wide range of variation in moisture content of fresh leaves which ranged from 64.4 to 76.94 *per cent*. The maximum value was found in Tr-10 followed by Tr-4 (75.99%) and minimum moisture percentage was recorded in Sujanpur-5. The moisture retention ranged from 57.39 to 71.41 *per cent* in 23 elite genotypes. Higher moisture retention was found in Tr-10 (71.41%) followed by Tr-4 (70.14%) and the minimum was noticed in Sujanpur-5 (57.39%) [49].

Leaf moisture retention capacity (%)

Among five mulberry varieties G-4 retained maximum moisture content (95.79%) followed by C-2038 (95.73%), S-1635 (94.94%), S-146 (94.67%) whereas minimum retention was noticed in Vishala (94.07 %) during chawki stage at 6 h (Table 1). During late age, among five mulberry varieties, Vishala retained maximum moisture content (96.16 %) followed by S - 1635 (96.03%), C-2038 (95.73%) and G-4 (95.68%), whereas minimum retention was noticed in S - 146 (95.21 %) at 6 h (Table 2). For overall mean, among five mulberry varieties C-2038 & G - 4 retained maximum moisture content (95.73%) followed by S - 1635 (95.48 %) and Vishala (95.12%), whereas minimum retention was noticed in S-146 (94.94 %) (Table 3). All the varieties showed statistically non - significant among each other for moisture retention capacity at 6 h for chawki stage, late age and overall mean (Table 1, 2 & 3).

All the varieties showed significant differences among each other for moisture retention capacity during chawki stage at 12 h, the variety C-2038 retained maximum moisture retention (92.71%) followed by G-4 (92.33%), S-1635 (91.90%) and Vishala (90.30%), whereas minimum moisture retention at 12 h was recorded in S 146 (87.84%) (Table 1). During late age, the variety C-2038 retained maximum moisture (92.09%) followed by S-146 (92.08%), Vishala (92.06%) and G-4 (91.93%) whereas minimum moisture retention at 12 h was recorded in S-1635 (91.28 %) at 12 h and showed non - significant among them (Table 2). For overall mean, there is statistical differences was observed among all the varieties for moisture retention capacity at 12 h, the variety C-2038 retained maximum moisture content (92.40%) followed by G-4 (92.13%), S-1635 (91.59%) and Vishala (91.18%), whereas minimum moisture retention at 12 h was recorded in S - 146 (89.96 %) (Table 3).

During chawki stage, higher moisture was retained in variety C - 2038 (89.17 %) followed by G - 4 (88.02 %), S - 1635 (87.52%) and Vishala (84.58 %), whereas, it was least in the variety S - 146 (81.97 %) and recorded significant differences among all the varieties at 24 h (Table 1). During late age rearing, higher moisture was retained in variety C - 2038 (86.34 %) followed by Vishala (84.72 %), S - 146 (84.60 %) and S - 1635 (84.26 %), whereas, it was least in variety G - 4 (83.88 %) at 24 h and showed non significant among all the varieties (Table 2). For overall mean, higher moisture was retained in variety C - 2038 (87.76 %) followed by G - 4 (85.95 %), S - 1635 (85.89 %) and Vishala (84.65 %), whereas, it was least in variety S - 146 (83.28 %). Among all the varieties there is significant differences was observed statistically at 24 h for overall mean (Table 3).

Higher moisture content and its retention capacity of leaves help to remain fresh for longer time acceptable to silkworms are related to thickness of leaves which in turn due to the ratio of palisade to parenchyma cells [16]. Size of the stomata and its frequency's role in moisture retention, transportation and CO_2 exchange rate was studied [51]. The moisture content and moisture retention capacity of leaves were higher in triploid genotypes even after the 12 hours of excision may be due to lower number of stomata per mm^2 [18] [12] & [48]. Framed the package of practices for cultivating five mulberry varieties *viz*., S30, S36, S41, S54 and K2 [25] [8].

There is a significant difference in moisture content at 8 and 24 h after harvest in leaves of six varieties of mulberry like Mysore local, Kanva-2, S-30, S-36, S-41 and S-54 was studied [13]. Twelve drought resistant mulberry varieties along with two cultivars for evaluation under natural stress (rain fed) condition. Moisture *per cent* and moisture retaining capability of leaves after 6, 12 and 24 h of excision were estimated. It was observed that the new mulberry varieties DTS-14, DRS-28, DRS-3 and DRS-34 retained more moisture in the leaves after 6, 12 and 24 hours of excision [52]. Since, Goshoerami is also triploid mulberry genotype, this may be the reason for its higher moisture retention percentage reported [3]. The studies on moisture *per cent* and moisture retention capacity in five mulberry varieties and concluded that S-36, S-30, K-2 varieties possessed maximum moisture *per cent* and moisture retention capacity as compared to other varieties [28]. The study reported that Mysore local variety possessed lower leaf moisture content and moisture retention, while English Black, KNG, Berhampore-5 variety had relatively higher moisture and moisture retention capacity out of eight mulberry varieties used for the study [6].

Evaluated four improved mulberry genotypes namely S-30, S-36, Viswa and M-5 for moisture content and moisture retention capacity. The leaf moisture content was significantly higher in Viswa (77.74 %) and S36 (77.24 %) genotypes. Leaf moisture loss at 6 h after harvest was significant loss in S-36 and S-30

genotypes (13.46 and 13.92 % respectively) [29]. The study on 16 diploid mulberry genotypes, 4 triploid genotypes and 5 induced tetraploids for leaf anatomical features. The results showed direct correlation between anatomical features, moisture content and moisture retention capacity of leaf are genotype specific [5]. Tikader and Roy (2003) conducted the experiment on 15 accessions for moisture *per cent* and recorded maximum values for Senmates (81.40 %) and lower in Kajli (56.83 %), moisture retention capacity was higher in Senmates (88.07 %) and lower in *M. indica* (35.21 %) [55]. The studies on five mulberry varieties for moisture *per cent* and moisture retention capacity which ranged from 74.15 to 79.00 *per cent*, 61.60 to 66.15 *per cent* respectively. The improved cultivars like S-13, S-34 and V-1 exhibited higher moisture content and moisture retention capacity of leaf compare to commercial cultivars like Kanva-2 and S-36 was reported [50].

Studies on leaf quality parameters in seven mulberry genotypes *viz*., V-1, V-2, V-4, K-2, S-13, S-36 and S-54 and reported higher leaf moisture content (LMC) and moisture retention capacity (MRC) in V-1 (75.93 and 82.17 %) followed by V-4 (75.67 and 81.64 %) and S-36 (75.14 and 81.27 %), while these two traits were found to be lowest in K-2 (69.50 and 76.25 %) was reported [17]. Leaves characterized by higher LMC and MRC were identified as superior quality leaves [6]. Also the above two traits are closely associated with the feeding efficiency and growth rate of silkworm larvae [41] & [6].

Variability for moisture retention capacity (MRC, measured as leaf relative water content after one to five hours of air drying) by screening 250 diverse mulberry accessions and the relationship between MRC and leaf surface (cuticular) wax was determined. Leaf MRC was significantly different among accessions and was found to correlate strongly with leaf surface wax. Moisture contents were high in tender followed by medium and coarse leaves was studied [30]. Moisture content and moisture retention capacity were significantly high in S1708 and lowest in C6 leaves was reported [34].

Table 1. Moisture content and moisture retention capacity of five different elite mulberry varieties for Chawki stage of silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture content (%)	Moisture retention capacity (%)		
		6 h	12 h	24 h
S 146	75.20 (60.10)	94.67 (76.68)	87.84 (69.57)	81.97 (64.85)
S1635	74.64 (59.74)	94.94 (77.16)	91.90 (73.52)	87.52 (69.30)
G4	75.40 (60.24)	95.79 (78.17)	92.33 (73.89)	88.02 (69.73)
Vishala	76.83 (61.20)	94.07 (75.92)	90.30 (71.83)	84.58 (66.85)
C 2038	76.61 (61.05)	95.73 (78.04)	92.71 (74.30)	89.17 (70.76)
CD @ 5 (%)	0.98	-	2.08	1.44
Sem±	0.31	0.97	0.65	0.45
CV (%)	0.88	2.19	1.55	1.15

Table 2. Moisture content and moisture retention capacity of five different elite mulberry varieties for Late-age rearing of silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture content (%)	Moisture retention capacity (%)		
		6 h	12 h	24 h
S 146	74.47 (59.63)	95.21 (77.33)	92.08 (73.63)	84.60 (66.87)
S1635	76.02 (60.66)	96.03 (78.48)	91.28 (72.88)	84.26 (66.60)
G4	72.98 (58.66)	95.68 (77.99)	91.93 (73.46)	83.88 (66.30)
Vishala	74.76 (59.82)	96.16 (78.70)	92.06 (73.64)	84.72 (66.97)
C 2038	77.24 (61.48)	95.73 (78.11)	92.09 (73.63)	86.34 (68.28)
CD @ 5 (%)	1.30	-	-	-
Sem±	0.41	0.60	0.72	0.42
CV (%)	1.18	1.34	1.71	1.09

Table 3. Overall mean of moisture content and moisture retention capacity of five different elite mulberry varieties for silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture content (%)	Moisture retention capacity (%)		
		6 h	12 h	24 h
S -146	74.84 (59.86)	94.94 (76.99)	89.96 (71.50)	83.28 (65.84)
S -1635	75.33 (60.19)	95.48 (77.74)	91.59 (73.13)	85.89 (67.91)
G-4	74.19 (59.44)	95.73 (78.06)	92.13 (73.67)	85.95 (67.96)
Vishala	75.80 (60.50)	95.12 (77.23)	91.18 (72.71)	84.65 (66.90)
C - 2038	76.93 (61.26)	95.73 (78.06)	92.40 (73.97)	87.76 (69.49)
CD @ 5 (%)	0.76	-	1.27	0.95
Sem±	0.24	0.61	0.39	0.30
CV (%)	0.69	1.38	0.94	0.76

Table 4. Evaluation index for moisture content and moisture retention capacity of five different elite mulberry varieties evaluated during chawki stage of silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture content (%)	Moisture retention capacity (%)			Average
		6 h	12 h	24 h	
C 2038	59.25	59.50	58.48	59.95	**59.30**
S 146	44.32	44.95	34.11	35.40	**39.69**
Vishala	61.61	36.70	46.41	44.28	**47.25**
G4	46.42	60.27	56.57	56.02	**54.82**
S1635	38.40	48.59	54.43	54.34	**48.94**

Table 5. Evaluation index for moisture content and moisture retention capacity of five different elite mulberry varieties evaluated during late age of silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture Content (%)	Moisture retention capacity			Average
		6 h	12 h	24 h	
C 2038	63.28	49.09	55.87	66.77	**58.75**
S 146	46.15	35.04	55.61	48.27	**46.27**
Vishala	47.93	60.78	54.97	49.60	**53.32**
G4	36.90	47.74	51.10	40.64	**44.10**
S1635	55.75	57.34	32.45	44.72	**47.56**

Table 6. Evaluation index of overall mean for moisture content and moisture retention capacity of five different elite mulberry varieties evaluated for silkworm, *Bombyx mori* L. during spring season (2019)

Variety	Moisture content (%)	Moisture retention capacity (%)			Average
		6 h	12 h	24 h	
C 2038	64.61	59.14	59.90	63.52	**61.79**
S 146	44.39	37.22	34.44	36.65	**38.18**
Vishala	53.68	42.08	47.15	44.85	**46.94**
G4	38.13	59.22	57.06	52.65	**51.76**
S1635	49.19	52.34	51.45	52.32	**51.33**

Evaluation index for mulberry varieties used during chawki and late age rearing w.r.t moisture content and moisture retention capacity

The mulberry varieties *viz*., S-146, S-1635, G-4, Vishala and C-2038 used for recording of moisture content and moisture retention capacity. During chawki rearing according to the evaluation index, the mulberry varieties were shortlisted as C-2038 having E.I value 59.30 followed by G-4 (54.82) respectively (Table 4). During late age rearing, according to the evaluation index, the mulberry varieties were shortlisted as C-2038 having E.I value 58.75 followed by Vishala (53.32) respectively (Table 5). According to the

evaluation index for overall mean, the mulberry varieties were shortlisted as C-2038 having E.I value 61.79 followed by G-4 (51.76) and S-1635 (51.33) respectively (Table 6).

Mulberry (*Morus* spp.) is an important plant forming the backbone of sericulture as it is the only food for silkworm. Due to its importance in silk producing areas, multiple varieties of mulberry have been developed suited to different agro climates and topographies and reported that due to heterozygous nature of mulberry, variability is high [11] and variations in characters have also been reported [10]. The findings reported that for multiple character analysis, evaluation index formed a good tool for determining the superiority of mulberry varieties. They however advocated the inclusion of feeding response to give the holistic results [33] & [39].

Seven mulberry varieties recorded mean evaluation index (E.I.) values of >50 ranging from 50.01 to 60.29, whereas, control (Sujanpur) scored E.I. value of 35.10 only. Three mulberry varieties, S-146 (60.29), Tr- 8 (52.42) and Tr-10 (52.17) recorded average E.I. value >52 for all the characters under sub-tropical conditions [45].

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