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Sustainable quality leaf production in S 1635 mulberry (*Morus alba*) under irrigated condition through organic nutrient management

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ABSTRACT

A field experiment was conducted during 2007-10 at the Central Sericultural Research and Training Institute, Berhampore (West Bengal), under irrigated Gangetic alluvial soil conditions, to study the effect of various organic nutrient management packages on soil health, growth attributes, leaf yield, leaf quality and economic gain in newly evolved, triploid, high yielding, recommended and popular S 1635 mulberry (*Morus alba* L.). Analysis of NPK status of soil was found to be improved in recommended practice, while available N was found marginally lower and available P and K were found higher in all the organic nutrient management packages over initial status. Analyzed data of three years (15 crops) with 7 treatments and 3 replication revealed that the effect of the treatments was found significant on plant height, branches/plant, leaves/plant, leaf area, leaf area index, leaf- shoot (%), leaf yield, leaf moisture, total chlorophyll and total soluble protein content in leaves. Maximum branches/plant was found in organic package (30 mt vermicompost/ha/year), while it was next best in leaves/plant, leaf yield (almost similar with integrated nutrient management package), total soluble protein and total soluble sugar content in leaves. During 3rd year, the overall leaf yield in organic packages with vermicompost, vermicompost plus vermiwash and integrated nutrient management package was found at par with recommended practice and obtained marginally higher (6.4%) leaf yield in vermicompost package. It was further noticed that the increase level in leaf yield with vermicompost package was reached at the tune of 32.57% in 2nd year over 1st year and 39.95% in 3rd year over 2nd year which was maximum among other treatments. Moreover, about 10.5% leaf yield was increased in vermicompost package during winter crops (November and February) of 3rd year. The economic gain on 3rd year leaf yield revealed that the organic package performed better in respect of about 6.4% more quality leaf yield (45.3 tonnes/ha/year), maximum net profit (₹ 22 697/ha/year) and return/ rupee investment (1.33) with marginally higher expenditure (₹ 67 931.13/ha/year) over recommended package.

Key words: Biofertilizers, Green manure, Leaf quality, Organic nutrient management, *Morus alba*, Sustainable leaf yield, Vermicompost

Mulberry (*Morus alba* L.) is a perennial, deep rooted and deciduous plant, cultivated in rural areas for its leaf available for more than 15-20 years. The leaf of mulberry is the only food of silkworm, *Bombyx mori* L., which produces silk being a vital component of the sericulture industry and helps to improve socio-economic status of the rural people. The quality of mulberry leaf plays a key role of about 37% success in silkworm rearing (Tazima 2001). Intensive cropping pattern of mulberry with 5 times whole shoot harvest per year, yielded about 90 mt green biomass/ha in S 1635 mulberry under Gangetic alluvial soil conditions of West Bengal, which causes depletion of about 500 kg N, 90 kg P_2O_5 and 300 kg K_2O/ha/year in soil.

Plenty of works have been done with vermicompost (VC), as one of the vital components of organic farming or IPNSS in many of the crops like gram, fodder maize, tomato, pea, cucumber, rice and *Solanum melongena* L. etc where growth, crop yield, crop quality, chlorophyll content, soil biological properties and soil health were found to be improved significantly and reduced the disease and pest incidences (Kale 1996, Jat and Ahlawat 2004, Azarmi *et al.* 2009, Tejada and Gonzalez 2009, Chauhan *et al*. 2010 and Chanda *et al*. 2011). Mandal *et al.* (1992) reported that *Sesbania rostrata* as green leaf manure was found potential to substitute chemical fertilizers, increased production of rice and enriched soil health.

The extent of replacement of inorganic sources of chemical nutrition through organic resources is little known in mulberry. Das *et al.*(1999) observed similar leaf yield, leaf

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quality in mulberry and economic characters of cocoons by the application of 50% reduced dose of vermicompost (10 mt/ha/year) and NPK (150:60:60 kg/ha/year) over full dose. Setua *et al.* (2002, 2007) found that among 4 types of composts, vermicompost was found to be the most efficient in overall improvement in mulberry and silkworm rearing which also increased leaf production significantly over FYM. It was further reported that either half dose of VC with full dose of NPK or full dose of VC with half dose of NPK contributed similar leaf yield in comparison with full dose of FYM and NPK (control). However, reduction of 50% each of VC and NPK reduced leaf yield by 9.2%.

The enormous need of quality leaf in turn to produce quality silk depends upon the good health of soil and availability of sufficient quality balanced nutrients using various organic resources like, green manure, vermicompost, biofertilizers and vermibed/vermiwash as biopesticides because of its antibiotic property so as to overcome the nutrient depletion (Zambare *et al.* 2008 and Subsashri 2004). It is pertinent to mention here that sericulture industry has a tremendous scope to produce quality vermicompost in a mass scale with the use of huge quantity (4.7 million tonnes) of organic refuges like rearing and farm waste, silkworm litters, waste leaf etc. Many promising components have been developed such as, vermicompost/compost, *Azotobacter chroococcum* as a nitrogen fixing bacteria (Sudhakar *et al.* 2000), arbuscular mycorrhizal fungi (*Glomus mosseae* / *G. fasciculatus*) as a phosphate mobilizing/solubilizing fungus (Setua *et al.* 1999) and green manuring with *Crotalaria juncea*/*Sesbania rostrata* or *S. aculeata* as nitrogen fixing root nodule *Rhizobium* bacteria (Setua *et al.* 2007) as a tool of INM by the Institute, but there was no comprehensive, integrated, low cost, eco-friendly, improved organic package available in respect of mulberry cultivation with quality vermicompost alone or with other treatment combinations for sustainable quality leaf production.

Thus, a new thrust on organic nutrient management practices especially with the use of vermicompost (VC), vermiwash, green manure and biofertilizers have been attempted which is expected to be substantial to improve the sericulture industry in the way of improvement in production of quality organic leaf to produce cocoon as well as organic silk. With a view to the above, a study was undertaken on the effect of vermicompost alone or in combination with other organic resources as mentioned earlier, with or without reduced dose of chemical fertilizers vis-à-vis recommended full dose of FYM and NPK (recommended practice) on soil health, plant growth, leaf yield and quality of a popular, triploid and high yielding S 1635 mulberry under irrigated, alluvial soil conditions of Gangetic plains of West Bengal along with economics.

MATERIALS AND METHODS

The experiment was undertaken during 2007–2010 at Berhampore, Murshidabad (West Bengal), under irrigated, Gangetic alluvial soil conditions. The pH of the soil was determined by following the method of Black (1965). Available/total N (Subbiah and Asija 1956), P and K in soil (Jackson 1973) before and after completion of a year were analyzed. Leaf moisture by oven drying method, total chlorophyll, total soluble protein, total soluble sugar content in leaf and leaf area were determined by following the method of Arnon (1949), Lowry *et al.* (1951), Morris (1948) and Satpathy *et al*. (1992) respectively. The total N, P_2O_5 and K_2O content of FYM and VC as used in the experiment were 0.54, 0.49, 1.54 and 1.5, 0.78 and 1.99% respectively.

AMF- inoculated and normal saplings of S 1635 mulberry (a triploid, high yielding, recommended and popular one), raised in nursery, were established in the experimental field in RBD with 3 replications at 60 cm × 60 cm spacing under irrigated condition (Ullal and Narasimhanna 1987) with seven different treatment combinations. T_1, control (no input), T_2, recommended practice (20 mt FYM/ha/year + 336N: 180P: 112K kg/ha/year), T_3, 30 mt VC/ha/year, T_4, 30 mt VC/ha/year + vermi wash (VW) @ 600 lt/ha/crop in 2 times as foliar spray, T_5, 25 mt VC/ha/year + green manuring (GM), *Crotalaria juncea* @ 25 kg/ha in June-July, T_6, 20 mt VC/ha/year + GM + AMF-inoculated (*Glomus mosseae)* saplings + *Azotobacter chroococcum* @ 20 kg/ha/year and T_7, INM package, 15 mt VC/ha/year + AMF-inoculated saplings (*Glomus mosseae*) + *Azotobacter chroococcum* @ 20 kg/ha/year + 50% recommended dose of N, P and K (168N: 90P: 56K kg/ha/year). The applied organic nutrients in different treatment combinations were meticulously calculated on the basis of total requirement of N, P and K in mulberry as available from mentioned resources.

The data on growth attributing characters and leaf yield were recorded in all the 5 seasons (July, Sept, Nov, Feb and April) followed by ground level pruning in April and 10-15-20-25 cm height pruning in subsequent crops. Application of organic and chemical fertilizers in 5 equal splits per year along with the incorporation of green biomass (4 mt/ha) of GM was done consecutively for 3 years. Season-/year-wise leaf yield as well as three years pooled data were statistically analyzed. Analysis of variance was done for 5 seasons of 3 consecutive years. The overall mean of each of the 7 treatments and critical difference value (P=0.05) for treatments, season × treatment and year × treatment interaction as well as economic gain were calculated.

RESULTS AND DISCUSSION

Effect of different organic nutrient management packages on soil nutrient status

The initial soil was sandy loam, slightly alkaline, pH 7.93, EC 0.15 dS/m and contained moderate available nitrogen (196 kg/ha) and low phosphorus (17 kg/ha) and high potassium (370 kg/ha). The analysis of soil status of 3 years pooled data revealed that the available P and K were found to be significant while N was at par in 1st and 2nd year. The 1st year trend indicated that the contents of nitrogen, phosphate and potash were marginally increased in organic packages while N was reduced and P and K were increased in second and third year (Table 1). It was further observed that application of various organic resources particularly vermicompost, could supplement N, P and K content in soil as exhausted by crop-wise leaf production like chemical fertilizers, thus VC proves to be efficient and potential because of slow increase in leaf yield.

Effect of different organic nutrient management packages on growth attributing characters

Analyzed data of three years revealed that the plant height, branches/plant, leaves/plant, leaf area, leaf area index, leaf- shoot (%) and leaf yield were found significant (Table 2). Maximum plant height was observed in T_2 (recommended practice) followed by T_7 (INM package). Highest branches/ plant were found in T_3 followed by T_4. Maximum number of leaves/plant was obtained in T_7 followed by T_3 and T_4 which was significantly higher over T_2. The maximum leaf area was registered in T_2 followed by T_7. Maximum LAI was registered in T_2 followed by T_7 and T_3. Maximum leaf-shoot (%) was obtained in T_1, control (no input) followed by T_6 and T_3 (Table 2). However, T_1 did not perform well in other parameters.

Effect of different organic nutrient management packages on leaf yield

The effects of the treatments, S × T (Table 3) and Y × T (Table 4) interactions were found significant on leaf yield. Overall maximum leaf yield was registered in T_2 followed by marginally lower leaf yield in T_7, T_3 and T_4, while least in

Table 1 Soil status of experimental field before and year-wise application of various organic nutrient management packages

Treatment	Available N (kg/ha)				Available P_2O_5 (kg/ha)				Available K_2O(kg/ha)			
	Initial	I yr	II Yr	III yr	Initial	I yr	II yr	III yr	Initial	Iyr	II yr	III yr
T_1	196	177	177	164	17	16	11	10	370	358	354	347
T_2		196	205	210		24	30	31		390	402	400
T_3		187	187	180		25	37	32		416	412	404
T_4		205	196	184		23	25	24		412	410	408
T_5		205	196	182		20	30	27		406	412	405
T_6		187	187	179		21	31	28		394	398	390
T_7		196	177	175		18	13	14		360	368	359
SEm(±)		6.52	7.26	6.33		1.67	1.61	1.21		9.92	6.66	8.25
CD (P= 0.05)		NS	NS	19.5		5.14	4.96	3.74		30.6	20.5	25.4
CV(%)		5.84	6.65	6.0		13.7	11.0	8.87		4.40	2.93	3.7

T_1, (control) no input; T_2, (recommended package) 20 mt FYM/ha/year + 336N: 180P: 112K kg/ha/year; T_3, 30 mt VC/ha/year; T_4, 30 mt VC/ha/year + VW @ 600 l/ha/crop in 2 times as foliar spray; T_5, 25 mt VC/ha/year + GM (*Crotalaria juncea)* @ 25 kg/ha in June-July; T_6, 20 mt VC/ha/year+GM+AMF-inoculated (*Glomus mosseae)* saplings + *Azotobacter chroococcum* @ 20 kg/ha/year; T_7, INM package, i e 15mt VC/ha/year + AMF-inoculated saplings + *Azotobacter chroococcum* @ 20 kg/ha/year + 50% recommended dose of N, P and K (168N: 90P: 56K kg/ha/year)

Table 2 Effect of various organic nutrient management packages on growth attributing characters, leaf-shoot (%) and leaf yield of mulberry (3 years pooled data)

Treatment	Plant height (cm)	Branches/ plant	Leaves/ plant	Leaf area (cm^2)	LAI	Leaf-shoot (%)	Leaf-shoot (kg/ha/crop)
T_1	81.38	8.15	117.3	95.04	3.14	66.63	3 195
T_2	130.82	9.14	151.8	161.65	6.74	58.73	7 601
T_3	114.15	9.78	153.6	141.04	6.10	63.13	6 808
T_4	112.35	9.50	153.3	136.71	5.76	62.77	6 136
T_5	114.42	8.51	151.9	141.19	5.97	62.75	5 753
T_6	105.28	8.89	139.3	139.23	5.39	64.04	5 252
T_7	121.32	9.43	159.7	144.26	6.31	60.98	7 195
CD (P= 0.05)							
(T)	4.17	0.54	11.9	9.39	0.64	1.59	316
CV(%)	9.0	14.33	19.44	16.49	27.46	6.10	12.68

Table 3 Effect of various organic nutrient management packages on leaf yield (kg/ha) (season-wise pooled data of 3 years)

Treatment	July	September	November	February	April	Mean	Annual
T_1	4 461	4 380	1 977	2 337	2 820	3 195	15 975
T_2	10 008	9 035	5 917	4 759	8 287	7 601	38 005
T_3	9 283	7 973	4 857	4 840	7 086	6 808	34 038
T_4	8 300	7 223	4 349	4 200	6 606	6 136	30 678
T_5	7 921	6 994	3 953	3 788	6 110	5 753	28 766
T_6	6 723	6 701	3 822	3 793	5 220	5 252	26 260
T_7	9 700	8 022	5 313	4 820	8 119	7 195	35 974
CD (P= 0.05)							
(S×T)			706				
CV(%)			12.68				

Table 4 Effect of various organic nutrient management packages on year-wise mulberry leaf yield (pooled data of 5 seasons)

Treatment	2007–08	2008–09	2009–10	Average
T_1	3 354	2 856	3 375	3 195
T_2	6 602	7 684	8 517	7 601
T_3	4 885	6 476	9 063	6 808
T_4	4 562	5 484	8 361	6 136
T_5	4 568	5 106	7 585	5 753
T_6	4 244	4 781	6 731	5 252
T_7	5 911	7 242	8 431	7 195
Average	4 875	5 661	7 438	
CD (P= 0.05)				
(Y×T)		547		
CV(%)		12.68		

T_6 and T_1. Congenial climate influenced maximum leaf production in July (26.89%) followed by September (24%), April (21.10%) and November (14.40%) and least in February (13.61%) which also supported the earlier findings of the Institute (Setua *et al.* 2002, 2007) irrespective of treatments and age of the plants (Table 3). Year-wise overall leaf yield data indicated a significant increasing trend among the treatments which registered 16.12% increase in 2nd year over 1st year and 31.38% increase in 3rd year over 2nd year (Table 4). It was also noticed that though there was leaf yield gap in T_3 over T_2 (recommended practice), but very marginal difference in leaf yield was observed among the two up to 2nd year in February (winter) crop season by the influence of organic resources particularly vermicompost, in spite of worst season for leaf production in comparison with July (best season) crop.

The trend indicated that when the leaf yield was increased by 16.39% in 2nd year over 1st year and 10.84% in 3rd year over 2nd year in T_2, the increase level reached at the tune of 32.57% and 39.95% in T_3 (organic package), 22.50% and 16.43% in T_7 (INM package) and 20.11% and 52.47% in T_4 (another organic package) respectively. However, during 3rd year, it was interestingly observed that the overall leaf yield was increased about 6.4% in T_3 (organic package) over T_2, whereas the leaf yield in T_4 (another organic package) and T_7 (INM package) was at par with T_2 (Table 5). Further, it was found that about 9.70%, 2.69% and 6.52% leaf yield were increased in T_3, T_4 and T_7 respectively in February crop (winter/adverse season) of 3rd year in comparison with T_2. After completion of third year, it was also noticed that when the leaf yield gap in T_3, T_4 and T_7 was 26.01%, 30.89% and 10.46% over T_2 in first year, the gap was reduced as 15.73%, 28.64% and 5.76% at the end of second year. Moreover, about 10.5% leaf yield was found to be increased in vermicompost package (T_3) in winter crops (November and February) of 3rd year over T_2.

Table 5 Effect of various organic nutrient management packages on leaf yield of 3rd year (kg/ha)

Treatment	July	September	November	February	April	Mean	Annual
T_1	5 034	3 736	2 166	2 817	3 121	3 375	16 874
T_2	12 988	7 887	6 574	5 936	9 199	8 517	42 584
T_3	13 439	8 615	7 313	6 511	9 437	9 063	45 315
T_4	12 343	8 037	6 292	6 096	9 036	8 361	41 804
T_5	11 817	7 692	4 894	5 444	8 080	7 585	37 927
T_6	9 451	7 333	5 312	4 917	6 642	6 731	33 655
T_7	12 514	7 733	6 380	6 323	9 207	8 431	42 157
CD (P= 0.05)	2 672	1 912	784	854	974		
CV(%)	13.55	14.74	7.93	8.84	7.00		

Table 6 Effect of various organic nutrient management packages on leaf quality (pooled data of 3 years* and 2 years)

Treatment	Leaf moisture* (%)	Total chlorophyll (mg/g fresh weight)	Total soluble protein (mg/g fresh weight)	Total soluble sugar (mg/g fresh weight)
T_1	75.50	1.46	16.98	42.08
T_2	78.34	2.19	23.32	40.76
T_3	77.85	1.82	23.30	41.66
T_4	77.34	1.70	22.26	40.68
T_5	78.48	1.83	21.67	40.57
T_6	77.10	1.64	20.53	39.13
T_7	77.91	1.80	22.11	40.97
CD (P= 0.05)	0.64	0.12	1.30	NS
CV(%)	1.98	13.42	11.89	9.77

Effect of different organic nutrient management packages on leaf quality

Analysis of variance revealed that the effects of the treatments were found significant on leaf moisture, total chlorophyll and total soluble protein (TSP) content in leaf while total soluble sugar (TSS) content in leaf was found at par. Highest leaf moisture (%) was obtained in T_5 followed by T_2 and least in T_1. Maximum total chlorophyll was registered in T_2 followed by T_5 and T_3 and least in T_1 (Table 6).Year-wise improvement in chlorophyll content of 5.79% was observed in 3rd year over 2nd year.

Maximum TSP content in leaf was observed in T_2 followed by T_3 (organic package) and least in T_1 (control) which confirmed that the leaf produced from zero level of inputs registered minimum quantity of TSP under stress condition. It was also found that the TSP content in leaf in T_3 was at par with T_2, T_4 and T_7. Year-wise increase in TSP was also registered 10.51% more in 3rd year over 2nd year (Table 6). Maximum TSS content in leaf was registered in T_1 followed by T_3 and least in T_6. It was interesting to note that as T_1 (control) comprises zero level of nutrients, the soluble form of TSS was found higher over others. However, an increasing trend of 11.21% TSS content in leaf was observed in 3rd year over 2nd year. Thus, the overall result indicated that the leaf quality was improved in organic packages particularly in T_3, T_4 and also in T_7 (INM package), except total chlorophyll content in leaf which was marginally lower in T_3, T_4 and T_7 over T_2.

Effect of promising organic nutrient management packages on economic gain

The economic gain on sustainable leaf yield of 3rd year revealed that the organic package (30 mt vermicompost/ha/year) performed better in respect of about 6.4% more quality leaf yield (45.3 tonnes/ha/year), maximum net profit of ₹ 22 697/ha/year as supported by Huang *et al.* (1993) in his findings and return/rupee investment (1.33) with marginally higher expenditure (₹ 67 931.13/ha/year) over recommended and other packages (Table 7). Though the expenditure in T_7 was less and overall performances were better than T_3, but the leaf yield, net profit and return/rupee were found lower.

The beneficial effect of organic resources resulted in slow improvement in growth attributes, leaf yield and quality due to proper decomposition, mineralization, solubilizing effects and availability of sufficient nutrients as observed in T_7 and T_3. This corroborated the findings of Katyal (2000), Das *et al.* (1999), Setua *et al.* (1999, 2002, 2007) and Sudhakar *et al.* (2000) in mulberry. Promising result with the application of vermicompost was also observed by Jat and Ahlawat (2004) in gram and fodder maize. Sustainable quality leaf yield of mulberry could be continued by continuous application of quality vermicompost under required soil moisture level and weed-free condition. The result thus supported the findings of Kler *et al*. (2000) who observed that the performance of chemical fertilizer was equivalent to organic inputs in long run (after a period of 3 years) with high or equal crop yields along with increase in organic carbon in soil thus supports organic farming in different cropping systems (Lampkin 1994, Katyal 2000 and Ramesh *et al*. 2005) particularly in mulberry to produce organic silk.

Table 7 Economic gain on promising packages vis-a-vis control (based on leaf yield of 3rd year)

Package/Treatment	Cost (₹ in thousand/ha/year)			Leaf yield (tonnes/ha/year)	Sale proceeds of leaf (@ ₹ 2000/tonnes) (₹ in thousand)	Net profit (₹/ha/year)	Return/Re investment
	Input	Labour	Total				
T_1 (control)	Nil	39.4	39.4	16.9	33.7	– 5 626	-
T_2 (rec. pac.)	15.7	50.9	66.6	42.6	85.2	18 552	1.28
T_3	24.0	43.9	67.9	45.3	90.6	22 697	1.33
T_4	26.6	56.2	82.8	41.8	83.6	828	1.01
T_7	16.6	48.4	65.0	42.2	84.3	19 321	1.30

Manday @ ₹ 70.00; Input: FYM @ Re 0.40/kg; VC @ Re 0.80/kg; Vermiwash @ Re 1.00/l; *Azotobacter chroococcum* @ ₹ 25/kg; Arbuscular mycorrhizal fungi @ ₹ 25/kg and the cost of NPK

It is, thus, inferred from the above study that the organic package, T_3 performed overall better and found potential over T_2 (recommended practice) from third year onwards in respect of about 6.4% more leaf yield with improved leaf quality, maximum net profit and return/rupee investment in spite of marginally higher expenditure. Moreover, T_3 is purely an eco-friendly as well as cost-effective package with slowly but steady improvement and did not comprise any chemical fertilizer and pesticides. Hence for the maintenance of soil health, to produce organic leaf for getting organic silk as per the demand of developed countries as well as an attempt towards organic farming approach in mulberry sericulture, the organic package, T_3 comprises of 30 mt quality vermicompost/ha/year may be recommended for mass practice at farmers' level in Gangetic alluvial plains under irrigated condition.

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REFERENCES

Azarmi R, Giglou M T and Hajieghrari B. 2009. The effect of sheep manure vermicompost on quantitative and qualitative properties of cucumber (*Cucumis sativus* L.) grown in the greenhouse. *African Journal of Biotechnology* **8**(19): 4 953–57.

Arnon D I. 1949. Copper enzymes in isolated chloroplasts polyphenol oxidase in *Beta vulgaris*. *Plant Physiology* **24**: 1–15.

Black C A. 1965. *Methods of Soil Analysis*. American Society of Agronomy Inc., Madison, Wisconsin, USA.

Chanda G K, Bhunia G and Chakraborty S K. 2011. The effect of vermicompost and other fertilizers on cultivation of tomato plants. *Journal of Horticulture and Forestry* **3**(2): 42–5.

Chauhan H S, Joshi S C and Rana D K. 2010. Response of vermicompost on growth and yield of pea (*Pisum sativum* L.) cv. Arkel. *Nature and Science* **8**(4): 18–21.

Das P K, Theertha Prasad B M, Bhogesha K, Katiyar R S, Vijayakumari K M and Madhava Rao Y R. 1999. Effect of graded doses of vermicompost of sericultural waste on mulberry growth, leaf yield and quality. *Proeedings of National Seminar on Tropical Sericulture. Theme: Sustainable Sericulture,* pp 28–30.

Jackson M L. 1973. *Soil Chemical Analysis*, pp 326–38. Prentice-Hall, New Delhi.

Jat R S and Ahlawat I P S. 2004. Effect of vermicompost , biofertilizer and phosphorus on growth, yield and nutrient uptake by gram *(Cicer arietinum)* and their residual effect on fodder maize *(Zea mays)*. *Indian Journal of Agricultural Sciences* **74**(7): 359–61.

Kale R D. 1996. Earthworms – the significant contributions to organic farming and sustainable agriculture. *Proceedings of National Seminar on organic farming and sustainable Agriculture,* organized by Association for Promotion of Organic Farming, held during 9-11 October 1996 at University of Agricultural Sciences, Bangalore, pp 52-7.

Lowry O H, Rosebrough N J, Farr A L and Randall R J. 1951. Protein measurements with Folin phenol reagent. *Journal of Biology and Chemistry* **193**: 265–75.

Mandal B K, Subuddhi U K and Singh Y V. 1992. Response of rice (*Oryza sativa*) to green-leaf manure and prilled urea. *Indian Journal of Agricultural Sciences* **62**(7): 432–5.

Morris D L. 1948. Quantitative determination of carbohydrates with Drey wood Anthrone reagent. *Science* **107**: 254–5.

Satpathy B, Shivnath, Rao K M, Ghosh P L and Nair B P.1992. An easy and rapid method of leaf area estimation in white mulberry (*Morus alba* L.) *Indian Journal of Agricultural Sciences* **62**: 489–91.

Setua G C, Kar R, Ghosh J K, Das K K and Sen S K. 1999. Influence of arbuscular mycorrhizae on growth, leaf yield and phosphorus in mulberry (*Morus alba* L.) under rainfed lateritic soil conditions. *Biology and Fertility of Soils* **29**: 98–103.

Setua G C, Banerjee N D, Sengupta T, Das N K, Ghosh J K and Saratchandra B. 2002. Comparative efficacy of different composts in "S1" mulberry (*Morus alba* L.) under rainfed condition. *Indian Journal of Agricultural Sciences* **72**(7): 389–92.

Subbiah B V and Asija G L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Current Science* **25**: 259–61.

Subsashri M. 2004. Vermiwash an effective biopesticide. *The Hindu*, Sept 30.

Sudhakar P, Gangawar S K, Satpathy B, Sahu P K, Ghosh J K and Saratchandra B. 2000. Evaluation of some nitrogen fixing bacteria for control of foliar disease of mulberry (*Morus alba*). *Indian Journal of Sericulture* **39**(1): 9–11.

Tazima Y. 2001. Silkworm, an important laboratory tool. Kodash L, Tokyo, pp 53–81

Tejada M and Gonzalez J L. 2009. Application of two vermicomposts on a rice crop: Effects on soil biological properties and rice quality and yield. *Agronomy Journal* **101**: 336–44.

Ullal S R and Narasimhanna M N.1987. Mulberry cultivation. *Indian Journal of Sericulture* **29**(2) : 263–72.

Zambare V P, Padul M V, Yadav A A and Shete T B. 2008. Vermiwash: Biochemical and microbiological approach as eco-friendly soil conditioner. *ARPN Journal of Agriculture and Biological Sciences* **3**(4): 1–5.