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Optimization of macronutrients application in *Terminalia tomentosa* (Asan) for sustainable tasar silk production

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Abstract

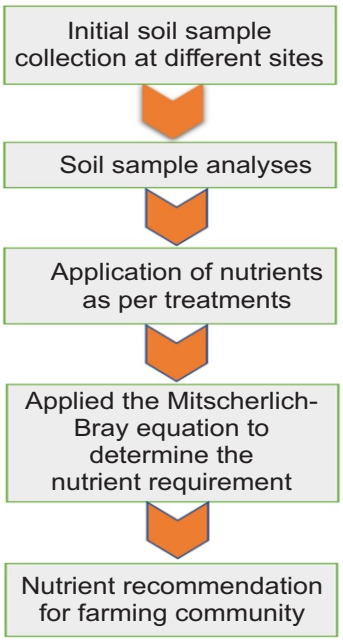
Aim: The aim of the present study was to optimise the nutrient requirements for *Terminalia tomentosa* (Asan) plant to increase the quality and quantity of leaves.

Methodology: This study used the Mitscherlich-Bray equation to formulate NPK requirements for the Asan plant. Independent experimental setups of N (5 levels), P (5 levels), and K (5 levels) designed in RCBD with three replications were carried out concurrently. Calculations were made to determine the theoretical maximum yield, the NPK constants c and c1, the NPK fertiliser recommendations for the Asan plant at various soil fertility levels, and the ideal fertiliser rates.

Results: Fertiliser recommendations were developed for a typical range of soil test values, but they still required additional field verification tests. The theoretical maximum yields determined by the Mitscherlich-Bray equation were 599.79g, 587.49 g, and 562.34 g per 50 leaves of the Asan plant for NPK, respectively. The study demonstrated that it is critical to consider the inherent soil fertility when developing fertiliser recommendations for Asan that will increase both leaf yield and overall productivity. It showed that soil K was less efficiently utilised by the Asan plant compared to the other soil nutrients. The c1/c ratio of the P experiment was lowest compared to the c1/c ratio values of N and K experiments, indicating that the Asan plant was more responsive to P fertilisation than other macronutrient fertilisation.

Interpretation: The fertiliser recommendation chart serves the farmers to manage the Asan plants and is more beneficial for harvesting quality cocoons without degrading the ecosystem.

Key words: Asan, Baripada, Macronutrients, Odisha, Tasar silk



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Introduction

Tropical tasar is an important Vanya silk variant, which is produced by the wild silkworm *Antheraea mylitta* Drury (Saturniidae: Lepidoptera). Since it is polyphagous in nature, it primarily hosts *Shorea robusta* (Sal), *Terminalia arjuna* (Arjun), and *Terminalia tomentosa* (Asan) (Suryanarayana *et al.,* 2005; Reddy, 2010). Raising Tasar silkworms is an integral element of tribal tribes' traditional cultures, particularly in the Mayurbhanj and Kendujhar districts of Odisha. In particular, the Kendujhar, Mayurbhanj and Sundargarh districts, which produce 90% of the state's tasars, have historically been significant traditional sites of employment for indigenous populations in the North-west Odisha. In the state, a total of 47,284 families depend on tasar sericulture for their livelihood, producing 107 MT of tasar raw silk per year (CSB, 2017). The necessity of nutrition quantity and quality is very precise in sericigenous insects for optimal physiological status and sustainable productivity (Pandiaraj *et al.,* 2017).

The availability of essential nutrients in food plants is indispensable for a successful life cycle, cocoon quality, metamorphosis to the moth stage, and their reproductive activity (Rath *et al.,* 2006; Reddy *et al.,* 2010). The growth and development of tasar silkworm larvae and the economic characteristics of cocoons are directly proportional to the nutritional contents of the leaves (Srivastava *et al.,* 2017). The macronutrients such as nitrogen (N), phosphorus (P), and potassium (K) are taken up by crops in huge quantities from the soil; therefore, it is necessary to replenish them to sustain the nutrient balance. Simultaneously, neglecting nutrient application results in the gradual depletion of soil nutrient-building capacity for both macro-and-micronutrients, as well as a decline in soil organic matter content, resulting in nutrient imbalances and soil fertility degradation (FAO, 1998). It is, therefore, it is essential to frequently monitor soil nutrition to sustain and ensure good health of the host plant. In this study, a soil test based on a targeted yield of host plants based on the Mitscherlisch-Bray equation was used in order to provide the host plants with adequate nutrients. The most well-known Mitscherlich equation was developed by E.A. Mitscherlich (1874–1956), a professor of agronomy in Berlin, Germany. Mitscherlich created an equation in 1909 that linked growth to the availability of plant nutrients based on Liebig's Law of Minimum (Harmsen, 2000).

He found that when plants were given enough nutrients, with the exception of one, their growth was proportionate to how much of the one limiting nutrient was added to the soil. Mathematically, this is expressed as dy/dx = (A-y) c, where dy is the increase in yield from an increment of the growth factor dx, dx is an increment of factor x, dy/dx is the rate of yield increase (slope), A is the maximum possible yield obtained from the growth factors supplied in optimum amounts, y is the yield obtained after a given quantity of factor x was applied, and c is the proportionality constant, which depends on the nature of the growth factor. In 1952, Roger Bray from the University of Illinois modified the Mitscherlich equation to include the native soil test value (b) and its efficiency factor (c). Log (A-y) =log A - c b - cx is the Mitscherlich-Bray equation. Several studies suggest that Mitscherlisch-Bray equation-based nutrient recommendations could be cost-effective and precise for plant nutrient requirements. Luz and Nenita (2020) reported that the use of blanket fertiliser recommendations can in sweet potatoes result in either under or over-application of fertilisers. Mitscherlich-Bray equation is useful in understanding the nutrient response of plants and in formulating fertiliser recommendations.

Similar, results were reported by Nemeth (2006) in wheat and corn crops and Afzal *et al.* (2014) in groundnut. Sonar and Babhulkar (2002) tested different sets of nutrient levels in wheat crops and found 80% of the theoretical maximum yield was superior to the blanket recommended dose. Mitscherlich-Bray equation-based N application significantly increased the leaf area, fresh herbage, total root yield, biomass, dry matter yield, shoot-root ratio, and marketable roots of sweet potato, according to Relente and Luz (2020). As a result, judicious fertiliser use is required for the Asan plant to produce maximum and sustainable biomass yield. However, the nutrient recommendation for the Asan plant is age-old and needs to be refined according to the current climatic conditions and different soil environments. So, an attempt was made with an objective to find out the optimum nutrient requirement (NPK) for the Asan plant using the Mitscherlich-Bray equation method.

Materials and Materials

An experiment was carried out in the Baripada, Mayurbhanj district of Odisha, India. Summers are hot and dry, with average temperature ranging from minimum 21.0°C to maximum 31.5°C. Most of the rainfall occurs during the south-west monsoons as the average rainfall is 1800 mm. The host plant, *Terminalia tomentosa* (Asan), was grown with separate sets of treatments imposed in different experimental plots, as mentioned in the nutrient treatment series (Table 1), with additional farm yard manure @ 12.5 mt ha^{-1} $year^{-1}$. All the experiments were critically designed in a complete randomised block design with three replications. The biomass yield obtained was subjected to Mitscherlich-Bray equation, *viz.,* log (A-y) = logA-c1b-cx, based on the principle that native and added nutrients have different efficiency factors (Bray, 1949); where "A" denotes the maximum yield possibility when all nutrients are present in adequate amounts but not in excess (this can be obtained using the SLAN concept), "y" denotes the yield obtained at a level of b, 'b' After finding the c1 and c values, the quantity of nutrients to be added to obtain the maximum possible yield could be worked out for different soil test values.

Based on the relationship between biomass yields, adding fertilisers, and the quantity of nutrients already existing in the soil, information was obtained on the efficiency factors for soil nutrients and fertilisers applied with reference to corresponding nutrients. The obtained information was then applied to the Mitscherlich-Bray equation. The ready reckoners for the

application of all fertilisers were developed in order to achieve the desired yield of tasar host plants for the common range of soil test values for the availability of nutrients under various tasar growing zones.

Results and Discussion

In this study, the leaf biomass yield of an Asan plant was quantified using the Mitscherlich–Bray equation. By adopting this equation, a theoretical maximum yield was calculated for different macronutrients by plotting log y against 1/x (Fig. 1). The coefficients of efficiency factors for soil (c1) and fertiliser (c) were computed in the experiment using this equation. The c1 value (0.0026) for K was smaller, followed by N (0.0029); the greater c1 value was found with P (0.0179), which indicated that soil K was less efficiently utilised by the Asan plant compared to other soil nutrients (Table 2). The ratio c1/c indicated the response of the Asan plant to fertiliser application. A higher ratio value indicated that the crop responded less to the applied fertiliser, while a lower ratio value indicated a greater crop response to the applied

Table 1: Different sets of nitrogen phosphorus and potassium treatments application in the experimental field

Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
0	0	0
50	20	20
100	40	40
150	60	60
200	80	80
With a common dose of P and K @ 50 kg ha^{-1} and 50 kg ha^{-1}, respectively	With a common dose of N and K @ 100 kg ha^{-1} and 50 kg ha^{-1}, respectively	With a common dose of N and P @ 100 kg ha^{-1} and 50 kg ha^{-1}, respectively

With a common dose of P and K @ 50 kg ha^{-1} and 50 kg ha^{-1}; With a common dose of N and K @ 100 kg ha^{-1} and 50 kg ha^{-1}; With a common dose of N and P @ 100 kg ha^{-1} and 50 kg ha^{-1}; with a common dose of NPK @ 100-50-50 kg ha^{-1}, respectively

Table 2: Leaf yields of *Terminalia tomentosa* and efficiency coefficients of soil and fertilizer macronutrients (N, P, K) as experiment conducted in RSRS, Baripada, Odisha

Treatments (x)	Actual leaf yield over 50 leaves (g)	Calculated log Y	1/x	c1	C	c1/c
N applied (kg ha^{-1})						
0	472	2.6739	0.0000	0.0029	0.0000	0.4699
50	555	2.7443	0.0200		0.0091	
100	578	2.7622	0.0100		0.0077	
150	581	2.7642	0.0067		0.0056	
200	558	2.7469	0.0050		0.0024	
Mean					0.0062	
P_2O_5 applied (kg ha^{-1})						
0	474	2.6758	0.0000	0.0179	0.0000	1.1288
20	531	2.7251	0.0500		0.0151	
40	556	2.7451	0.0250		0.0139	
60	583	2.7657	0.0167		0.0234	
80	572	2.7574	0.0125		0.0108	
Mean					0.0158	
Theoretical maximum yield (A): 587.49 g						
K_2O applied (kg ha^{-1})						
0	482	2.6830	0.0000	0.0026	0.0000	0.1652
20	523	2.7185	0.0500		0.0155	
40	543	2.7348	0.0250		0.0155	
60	559	2.7474	0.0167		0.0230	
80	547	2.7380	0.0125		0.0090	
Mean					0.0157	
Theoretical maximum yield (A): 562.34 g						

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Table. 3: Fertilizer recommendations chart of macronutrients (N, P, K) for *Terminalia tomentosa* based on the Mitscherlich – Bray concept for Baripada, Odisha state

Soil available nutrient (kg ha^{-1})	Percent of theoretical yield of leaf biomass		
	80	**85**	**90**
Nitrogen (N)			
50	89	109	137
100	66	86	114
150	42	62	90
200	19	39	67
250	0	15	43
300	0	0	20
350	0	0	0
Phosphorous (P_2O_5)			
10	32	41	52
20	22	30	41
30	10	18	29
40	0	7	18
50	0	0	7
60	0	0	0
Potassium (K_2O)			
50	36	44	55
100	28	36	47
150	20	28	39
200	11	19	30
250	3	11	22
300	0	3	14
350	0	0	6
400	0	0	0

fertiliser (Sonar and Babhulkar, 2002). The c1/c ratio of the P experiment was lowest compared to the c1/c ratio values of N and K experiments, indicating that the Asan plant was more responsive to P fertilisation than other macronutrient fertilisation. The results of this study showed that relying solely on soil tests to determine fertilizer recommendations is unreliable. This is due to the fact that the soil could only produce 50 and 70 per cent of the maximum yield even when it contained adequate levels of nutrients. The study showed that for higher leaf biomass yield, fertilisation was still required even when the soil contained adequate amounts of nutrients naturally.

It is not only incorrect and unscientific, but it is also wasteful to use "blanket fertiliser recommendations" for a specific crop regardless of the site or soil conditions. Applying fertiliser in low or excessive amounts is a possibility. The former will produce a low and unprofitable yield, whereas the latter will raise production costs and may have a long-term negative impact on the environment. The Mitscherlich equation, whether in its original or modified form, is an effective tool for determining fertiliser recommendations and gauging how well crops respond to fertilisation. The Mitscherlich-Bray modification makes the equation more useful for developing site-specific fertiliser recommendations by incorporating both soil test results and crop response to fertilisation. According to Dudal and Roy (1995), conceptual, analytical, and simulation models are necessary for the development and application of integrated nutrient management systems in order to provide a framework for the integration of various system components. The Mitscherlich equation is a potential tool for such purpose.

Table 3 shows that fertiliser recommendations were derived from the leaf yield data of different experiments using the Mitscherlich-Bray equation. These recommendations can provide a choice for yield target depending on the inherent soil fertility levels. For example, fertiliser recommendations for soil with available soil nutrients of N = 50, P = 10, and K = 50 kg ha^{-1} would be 89, 32, and 36 kg ha^{-1}, respectively, to attain 80 per cent of the maximum yield. Similarly, fertiliser recommendation charts for other nutrients have also been given to attain 80, 85, and 90 per cent of the maximum theoretical yield. This result indicates that with an increase in soil test values for different nutrients, there

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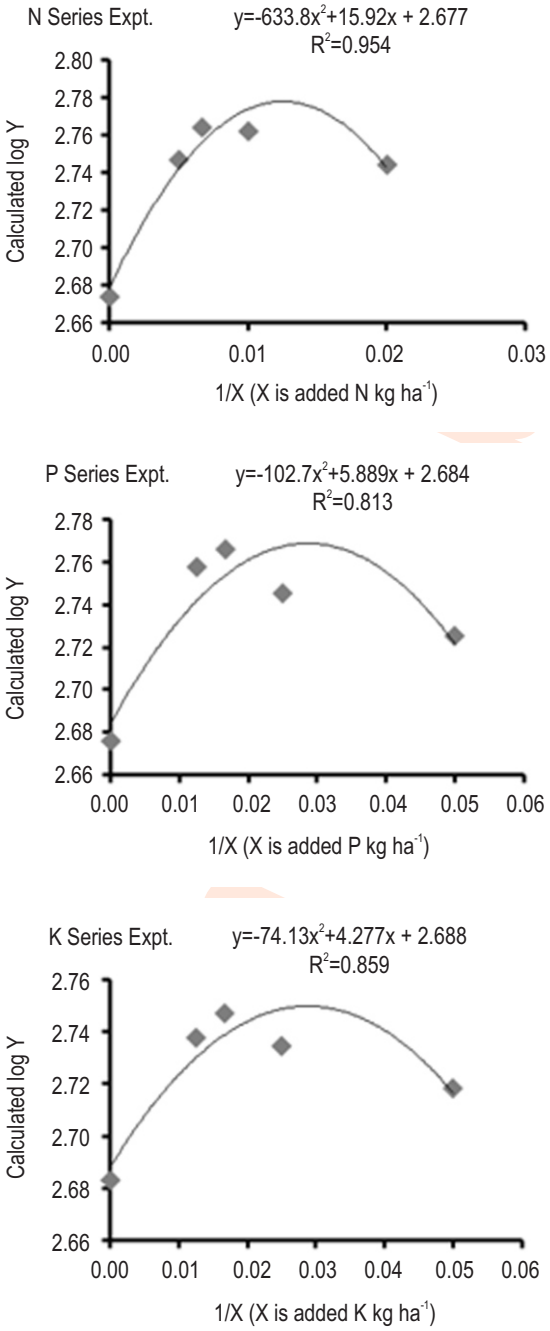

Fig. 1: Theoretical maximum yield (A) of *Terminalia tomentosa* from the plot of log Y vs. 1/x as affected by levels of macronutrients (N, P, K) application in RSRS, Baripada, Odisha

was a corresponding decrease in the nutrients. For achieving the maximum targeted yield, as fixed in this study at 90 per cent, one has to apply nitrogenous fertiliser weighing approximately 137, 114, 90, 67, 43 and 20 kg ha^{-1} with soil test values of 50, 100, 150, 200, 250, and 300 kg N ha^{-1}, respectively. Likewise, fertiliser recommendations for other nutrients were given with a different range of soil test values against different percentages of the theoretical yield of leaf biomass.

This modified equation has been successfully used by Sonar and Babhulkar (2002), Afzal *et al.* (2014), Abid Ali *et al.,* (2022), Dimkpa *et al*., (2020) to evaluate fertiliser response and

crop requirements. Nemeth (2006) reported higher yields and profits possible in wheat crops using the Mitscherlich-Bray equation. Sonar and Babhulkar (2002) reported an 85% theoretical yield that could produce a higher wheat yield in all locations. It is credible to enhance the fertiliser use efficiency and economise its use for sustainable Tasar silk production. To achieve a high percentage of relative yields, the equation can very well be suited to conditions of low to high soil fertility. This has an added advantage in determining fertiliser requirements under a high buildup of available nutrients in successful cropping. This can serve as a wonderful tool for fertiliser recommendations for sustainable Tasar silk production.

It can be concluded that nutrient recommendation based on Mitscherlich-Bray prescription will help to minimise the nutrients applied from oversupply to the host plants, which could save the environment from overfertilization, which leads to degrading soil quality. Furthermore, site-specific nutrient requirements for increased productivity have been developed. So that this ready reckoner table serves the purpose of sustainable production of Tasar silkworms.

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Authors' contribution: J. Singh: Conceptualization and designing of the experiments; collection of soil samples from study regions, lab experiments; **Pandiaraj:** Conceptualization and designing of the experiments; Preparation of manuscript; **S. Das:** Technical support in lab work; Preparation of manuscript; **K Sathyanarayana:** Support in execution of work; **S. Giri:** Preparation of manuscript; **P. K. Kar:** Preparation of manuscript; **M. Patnaik:** Collection of soil samples from study regions; **B. Patnaik :** Collection of soil samples from study regions.

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References

Abid Ali, W. A., L. Ali, N. Manzoor, S. W. Hussain Shah, A, Rehman Ch., S. Afzal, M. Islam, B. Ali, L. H. Akhtar and G. Nabi: Application of Mitscherlich–Bray equation for fertilizer use on Raya. *Pak-Euro J. Medi. Life Sci.*, **5**, 301-308 (2022).

Afzal, S., M. Islam and Obaid-Ur-Rehman: Application of Mitscherlich-Bray Equation for fertilizer use in groundnut. *Communi. Soil Sci. Plant Anal.,* **45**, 1636-1645 (2014).

Bray, R.H.: Diagnostic Techniques for Soils and Crops. American Potash Institute, Washington D.C., pp. 53-86 (1949).

CSB: Tasar value chain analysis- A summary: Odisha. Published by CSB, Bangalore and Pradhan, pp. 43-57 (2017).

Dimkpa, C.O., J. Fugice, U. Singh and T.D. Lewis: Development of fertilizers for enhanced nitrogen use efficiency–Trends and perspectives. *Sci. Total Environ*., **731**, 34-51 (2020).

Dudal, R. and R.N. Roy: Integrated Plant Nutrition Systems. Report of expert consultation, 13-15 December 1993. FAO, Rome, Italy pp. 13-15 (1995).

FAO: World Reference Base for Soil Resources. World Soil Resources Report, No.84. Rome, FAO (1998).

Harmsen, K.: A modified Mitscherlich equation for rainfed crop production in semi-arid areas: 1. Theory, **48**, 237-250 (2000).

Liz, G.A. and Nenita E. de la Cruz: Application of Mitscherlisch-Bray equation to formulate fertilizer recommendations for sweet potato in Leyte, Philippines. *Ann. Trop. Res.,* **42**, 30-42 (2020).

Nemeth, T.: Application of the Bray–Mitscherlich Equation approach for economically and environmentally Sound fertilization of field crops in hungary. *Communi. Soil Sci. Plant Anal.,* **37**, 15-20 (2006).

Pandiaraj, T., P.P. Srivastava, S. Das and A.K. Sinha: Evaluation of soil fertility status for soil health card in various Tasar growing fields of Bihar and Jharkhand states, India. *Int. J. Curr. Microbiol. App. Sci.,* **6**, 1685-1693 (2017).

Rath, S.S., M.K. Singh and N. Suryanarayana: Changes in the rate of feeding and assimilation in *Antheraea mylitta* fed on two major food plants and its effect on silk production and reproduction. *Int. J. Indus. Entomol.,* **29**, 24-27 (2006).

Reddy, R.M.: Silkworm food plants apply dimension under Indian condition-time for utility optimization and value addition. *Sericologia*, **50**, 1-17 (2010).

Relente, F.C. and L.G. Asio: Nitrogen application improved the growth and yield performance of sweet potato (*Pomoea batatas* L. Lam). *Ann. Trop. Res.,* **42**, 45-55 (2020).

Sonar, K.R. and V.P. Babhulkar: Application of Mitscherlich-Bray Equation for fertilizer use in wheat. *Communi. Soil Sci. Plant Anal.,* **33**, 3241-3249 (2002).

Srivastava, P.P., T. Pandiaraj, S. Das and A.K. Sinha: Characteristics of soil organic carbon, total nitrogen and C/N ratio in Tasar silkworm growing regions of Jharkhand and Bihar states. *Imp. J. Interdiscipli. Res.,* **3**, 426-429 (2017).

Suryanarayana, N., R. Kumar and Gargi: Monograph on Indian Tropical Tasar silkworm food plants (*Terminalia* Spp.). Central Tasar Research and Training Institute, Central Silk Board, Ranchi, India, pp. 1-115 (2005).