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Volume 50, 2024

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Preface

Tea is a harmonious blend of art and science, including innovative and sustainable agricultural practices. The tea industry of Bangladesh is a vital sector, not only as a significant contributor to the national economy but also as an integral part of the cultural and social fabric of the country. Our tea industry has a rich history dating back to the British colonial era. Over the decades, it has evolved and adapted to changing agricultural practices, market demands and climatic conditions. Today, the country stands as one of the leading tea producers in the world, renowned for its high-quality tea that competes on the global stage.

With great pleasure, I would like to inform that Bangladesh Tea Research Institute (BTRI) is going to publish the 50th volume of the 'Tea Journal of Bangladesh'. This journal aims to bring together a diverse array of research articles, reviews and case studies that highlight the multifaceted aspects of tea in Bangladesh. We have included contributions from leading experts in tea science & technology. Their insights and findings not only advance our understanding of tea cultivation and production but also address the challenges and opportunities facing the industry today.

We are grateful to the authors for their valuable contributions and to the peer reviewers for their rigorous evaluations that ensured the high quality of the journal. Our heartfelt thanks to the editorial team for their dedication and hard work in bringing this journal to fruition.

We hope this journal will serve as an essential resource for researchers, policymakers, industry stakeholders, and anyone interested in the dynamic field of tea science in Bangladesh. Notwithstanding every attempt, this journal may contain inadvertent mistakes in various forms. We ardently request our valuable readers to pardon us for such unintentional mistakes and shall consider ourselves rewarded for receiving any evocative criticism. Finally, I hope that the knowledge shared within these pages will foster innovation, inform policy and ultimately contribute to the sustainable growth and prosperity of the tea industry in Bangladesh.

Major General Md. Ashraful Islam, ndc, psc
Chief Advisor
Tea Journal of Bangladesh

Editorial

The 50th volume of Tea Journal of Bangladesh contains seven research articles.

The first article is on role of 'Bangladesh Tea Board' on enhancing productivity and quality of Bangladesh tea. There are about 168 tea estates producing about 102.92 million kg of made tea in 2023 which is a record for the tea history of Bangladesh. But due to local consumption and other considerations, Bangladesh tea is nearly extinct from the traditional worldwide markets. A 'Roadmap for Development: Bangladesh Tea Industry' was initiated by Bangladesh Tea Board, including 11 action strategies for the development of the tea industry and to boost up production about 140 million kg by 2025, meeting both domestic consumption and resuming foreign tea exports. Currently, Bangladesh Tea Board is also focusing intensively on research about varietal improvement, modern planting techniques, integrated disease and pest management, modern tea manufacturing technologies, tea export strategies etc. with proper extension of plantation in different region of Bangladesh providing sufficient training as well as planting materials and machineries for enhancing productivity and quality of Bangladesh Tea.

The second study was conducted to analyze the effectiveness of national environment policy to reduce pesticide pollution in the tea sector. For the survey, relevant data were collected from secondary and primary sources such as books, journals, newspapers, and websites. Both quantitative and qualitative information were used to conduct the study. Data were also collected through questionnaires, interviews, Focus Group Discussions (FGD), and online surveys. It was found that majority of respondents agreed about awareness building, training & motivation, the introduction of IPM in the tea gardens, organic farming, punishment, and finally, updating the policy could make environment policy more effective in the tea sector.

In our country, there is no uniform and standard tea tasting scoring or scaling method which can be followed by different tea estates, factories, broker houses or other organizations related to tea business. Besides, in recent times, Bangladesh Tea Board has fixed the base price of tea auction price in accordance with the quality of tea to deal with the unstable situation caused by the lower price of tea prevailing in the country. So, there is a need for standardization of quality assessment parameters of 'Organoleptic Tasting Method' that represents all teas of different qualities produced in our country as well as through which the quality of different teas can be determined in the same way. The third paper will give a proper and ideal guideline for organoleptic tea tasting and its different quality assessment parameters including dry leaf appearances, infused leaf appearances and liquor characteristics.

The fourth article is about development of sustainable manufacturing protocol of 'golden tips tea' with different clonal combinations in respect of Bangladesh. 'Golden Tips Tea' is a kind of 'White Tea' that differs from its golden colour appearance and some extra flavour. In Bangladesh, there is not enough literature or production manufacturing knowledge about Golden Tips Tea thus planters are still more or less ignorant about Golden Tips Tea processing. This paper will give a concrete idea about the standardized manufacturing & processing protocol of Golden Tips Tea using different clonal combinations of Bangladesh.

The fifth article titled as 'Effect of grafting technique to produce composite tea plant in the nursery for higher yield and drought resistance capacity'. Environmental factors play a major role in tea growing and tea plants are vulnerable to water deficiency stress. Grafting is one of the techniques that have been developed to help crops become more resilient to drought stress. The current study was aimed to develop drought resistant tea plants as well as to increase the yield by grafting technique of different rootstock and scion combinations.

Uncontrolled weed growth in tea plantations can result in a 10–50% reduction in yield. The sixth article is about an experiment which was conducted at the Bangladesh Tea Research Institute Farm & Bilashcherra Experimental Farm during 2019–2020 to determine the best weed management combinations for managing weeds in matured tea plantations. Considering yield of made tea and economic analysis viewpoint it can be concluded that the application of Indaziflam and Paraquat following a chilling operation provides the highest percentage of weed reduction and the longest duration of weed-free conditions.

The last article is about the response of bio-slurry based compost on soil properties and yield of mature tea. Bio-slurry is an organic substance produced as a byproduct of biogas facilities via anaerobic digestion of methane gas. By using 3 tons/ha bio-slurry based compost in tea plantation can reduce 30% use of chemical fertilizers and thus ensure agricultural sustainability and further reduce environmental pollution. The findings also revealed that applying bio-slurry based compost and chemical fertilizers combinedly has some significant advantages in the production of tea and improvement of tea soil quality.

(Dr. Md. Ismail Hossain)
Chief Editor

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ROLE OF BANGLADESH TEA BOARD ON ENHANCING PRODUCTIVITY AND QUALITY OF BANGLADESH TEA

Major General Md. Ashraful Islam, *ndc, psc**

Abstract

Since ancient times, tea has been acknowledged as a health-promoting beverage, and it is one of the most significant non-alcoholic beverages worldwide. In Bangladesh, tea cultivation was started first near the Chittagong Club in the 1840s and Malnicherra Tea Estate in Sylhet is the first tea estate in Bangladesh established in 1854. Tea industry of Bangladesh is one of the key sources of income for the national treasury, accounting for 1% of the nation's GDP. Bangladesh Tea Board is a statutory body, was formed for the development of the tea industry through the Tea Ordinance 1977, which is now functioning by the Tea Act, 2016. There are two institutions under Bangladesh Tea Board: Bangladesh Tea Research Institute (BTRI) and Project Development Unit (PDU). There are about 168 tea estates producing about 102.92 million kg of made tea in 2023, which is a record for the tea history of Bangladesh. However, due to local consumption and other considerations, Bangladesh tea is nearly extinct from traditional worldwide markets. In 1980, 30.98 million kg were exported, accounting for 77.37% of the entire production; by 2023, however, exports accounted for just 1.01% of total tea produced. We used to be a tea exporting country once, but now we import tea since our consumption of tea exceeds our production. A 'Roadmap for Development: Bangladesh Tea Industry' was initiated by Bangladesh Tea Board, including 11 action strategies for the development of the tea industry and to boost production of about 140 million kg by 2025, meeting both domestic consumption and resuming foreign tea exports. Currently, Bangladesh Tea Board is also focusing intensively on research about varietal improvement, modern planting techniques, integrated disease and pest management, modern tea manufacturing technologies, tea export strategies, etc., with proper extension of plantation in different regions of Bangladesh providing sufficient training as well as planting materials and machineries for enhancing productivity and quality of Bangladesh Tea.

Keywords: Bangladesh Tea, Quality, Production, Bangladesh Tea Research Institute, Project Development Unit

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Introduction

Due to its enormous economic significance, tea (*Camellia sinensis* (L.) Kuntze, Theaceae) is an important agricultural crop that is produced all over the world (Das et al., 2015 ; Yang et al., 2015). One of the most widely consumed non-alcoholic beverages in the world, tea is becoming more and more well-known as a "health drink" due to its potential medical benefits. Throughout ancient times, tea consumption has been associated with health benefits (Khan and Mukhtar, 2019). Almost two-thirds of people in the entire world have it every morning (Kurahashi et al, 2008).

In Bangladesh, tea was first grown in the 1840s adjacent to the 'Chittagong Club'(Nasir and Shamsuddoha, 2012). The earliest tea estate in Bangladesh was Malnicherra Tea Estate in Sylhet, which was founded in 1854 and began commercial production in 1857 (TTAB, 2024). There are about 168 tea estates producing about 102.92 million kg of made tea in 2023, which is a record of the tea history of Bangladesh (BTB, 2023). Tea industry of Bangladesh is one of the key sources of income for the national treasury, accounting for 1% of the nation's GDP (Raza, 2019). Bangladesh is ranked 8th in terms of production around the world (ITC, 2022).

While tea production reached from 18.36 million kg to 102.918 million kg between 1947 and 2023, tea exports dropped to 96.64% during the past 43 years (from 1980 to 2023). In 1980, 30.98 million kg were exported, accounting for 77.37% of the entire production; by 2023, however, exports accounted for just 1.01% of total tea produced. The primary cause was the exceptionally high level of consumption, which increased as the population and the quantity of tea produced increased.

Currently, Bangladesh tea sector has faced a lot of difficulties. Due to high rainfall, drought, leaching of nutrients and water, crop removal, lack of modern machinery and equipment, lack of capital, lack of skilled manpower, lower market value, low-yielding seedling plants, old plantations, inadequate shade trees, soil and climatic properties, lack of proper irrigation and drainage systems, lack of educational facilities for the labors, discrimination between male and female workers, etc. the production of Bangladesh tea is not adequately stable (Rahman, 2006). Thus, there is an urgent need to strengthen the tea manufacturing industry in Bangladesh, devoting particular attention to the quality, productivity, and cost of tea as well as the marketing system (Islam et al., 2005). The tea industry of Bangladesh may pursue its objectives by implementing intensive plantations that include elite clones and seed stocks. However, as there is no additional land available for expanding the tea plantation, it is necessary to enhance the current areas by introducing high-yield and high-quality clones. By filling vacancies and planting new improved clones in areas where old tea plants have been discarded, tea production may be increased towards the intended objectives, making the old tea estates economically viable. So, tea planters should prioritize the use of enhanced cultivars that meet the industry's needs (Palni et al., 1999).

Bangladesh Tea Board is a statutory body which was formed for the development of tea industry. In 1977, Tea Ordinance-1959 was repealed and Tea Ordinance-1977 was issued and Bangladesh Tea Board was established under this Ordinance. Bangladesh Tea Board is being managed as per the Tea Act, 2016. There are two institutions under Bangladesh Tea Board are: Bangladesh Tea Research Institute (BTRI) and Project Development Unit (PDU). The main aim of Bangladesh Tea Research Institute is to increase productivity and quality through scientific research, to provide science-based advice and support in the development and excellence of the tea industry, and to spread the latest technology in the tea industry. On the other hand, the main mission of Project Development Unit (PDU) is to maximize tea production & quality by utilizing whole tea cultivable land in Bangladesh, motivating small holding tea cultivation and exporting tea after meeting our local demand (BTB, 2024; BTRI, 2024 and PDU, 2024). Bangladesh Tea Board is now focusing intensively on research about varietal improvement, modern planting techniques, integrated disease and pest management, modern tea manufacturing technologies, tea export strategies etc., with the proper extension of plantation in different regions of Bangladesh providing sufficient training as well as planting materials and machinery for enhancing productivity and quality of Bangladesh Tea.

History of Bangladesh Tea Industry

In the early 1800s, tea cultivation began in Assam and adjacent areas of India. Tea cultivation began in Bangladesh in the early 1840s. The early history of tea in Bangladesh is the history of tea in Northeast India, particularly the history of Surma Valley. The period 1827-1857 is very significant as the beginning of tea cultivation in the subcontinent, especially for Bangladesh. The latter part of this period saw the expansion of tea cultivation in the greater Sylhet and greater Chittagong districts of Bangladesh. Tea cultivation started in Chittagong in 1839-40 (Ahmmed, 2021; Mamun, 2019).

The tea plants were mainly seeded hybrids, but there were also some local Assamese and China type tea plants. In 1840, District Collector Mr. Scones first collected some tea seeds from Assam and some Chinese type tea plants from the Kolkata Botanical Garden and planted them in front of the Chittagong Club, known as 'Kunduder Bagan'. Chittagong's first tea garden was the 'Pioneer' indeed. But unfortunately, this tea-cultivation initiative did not survive. Another gentleman Mr. Hogg, personally cultivates an acre or two of tea in spades across the Karnaphuli River. This was the second attempt at tea cultivation. Finally, the first tea was prepared in Chittagong in 1843. Meanwhile, remarkable progress has been made in Assam. The presence of local tea plants in the Chandkhani hills of Sylhet was found in 1855 (Ahmed, 1963).

In the same year, tea cultivation began in the Surma Valley comprising various districts of Cachar and Sylhet. A few years later, tea plants were discovered in their natural state in the Khasia and Jaintia hills bordering Sylhet district. Then in 1854, Malanichhara tea plantation was established near Airport Road in Sylhet city in 1847. Originally, Malnichrai was the first commercial tea garden in Bangladesh. Formerly, the tea sector in Bangladesh was closely linked to the tea production in North East India. As a result, the Tocklai Experimental Station of India provided scientific assistance to the tea industry in Bangladesh (Alam, 1992).

Post-Partition 1947

Prior to the partition and until 1947, teas made in the Sylhet and Surmah valleys were referred to be Indian teas, but were also recognized as Sweet liquoring Surmah valley teas. All the teas were produced using the Orthodox method, and their quality was very close to that of teas from the nearby Cachar area. There was apparently limited Legg-Cut and green tea manufacturing prior to 1947. Towards the end of the 19th century, the expansion of tea business concentrated towards the establishment of various Limited liability companies such as M/S Duncan Brothers & Co. Ltd., James Finlay & Co. and Octovious Steel & Co. Ltd., M/S Macneill & Co. Ltd. By 1903, there were 15 European planters in North Sylhet, 102 in South Sylhet (Moulvibazar) and 26 in Hobigonj region of larger Sylhet (Mamun, 2011).

Post-Partition 1947-1971

After partition, the subcontinent was basically divided into two political territories - India and Pakistan (comprising West and East Pakistan) (Ferdous, 2021). There were 133 tea estates in Pakistan in 1947 when it gained its independence. By 1971, this number had increased to 147, representing around 90,000 workers out of the 249,000 people that resided across the nation (Hossain, 2018).

The 1971 War of Liberation

The tea sector faced several challenges in 1971 during the War of Liberation. Along with the destruction to several factories, two-thirds of the veteran planters of British and Pakistani descent abandoned the business while many senior Bangladeshi planters served in the war. This implied that the estates were being managed by unskilled individuals who had to deal with unsettling circumstances. In fact, several of the battling happened just next to the borders, in the tea garden regions. The bungalow of the manager of 'Teliapara Tea Estate' served as the first place of assembly for the senior officers of the Eastern Sector of the Liberation War after the crackdown on April 4, 1971. This bungalow later served as the headquarters of the Bangladesh Forces Headquarters (BDFHQ) for a considerable amount of time (Bhuyan, 2014).

After 1971, War of Liberation

Right after the war, England was a readily accessible source of support. In 1973, the British organization Overseas Development Administration (ODA), at the insistence of the Government of Bangladesh, assigned the Commonwealth Development Corporation (CDC) with evaluating the prerequisites for a process of revitalization and restructuring the tea sector, including tea growing, manufacture, research, markets and market organization, with an assessment of the financial and economic returns to such a program. Furthermore, the government-backed Dastagir Committee, which investigated the financial limitations of many estates, offered its suggestions in 1976; they turned out to be very successful. The Bangladesh Tea Board was reformed in 1977 with goals similar to those of the previous Pakistan Tea Board, which had been established by the Pakistan Tea Act of 1950. The Tea Board's role as oversight across Bangladesh's tea industry has grown to include crop monitoring and disposal, export license issuance to buyers, permission to permit producers to sell directly to consumers and consignment, among other things.

The Tea Traders Association of Pakistan was replaced in 1974 by the Tea Traders Association of Bangladesh. After eight years, the imperial method of weight was replaced with the metric system for tea marketing. During 1975-76, in an attempt to increase yields, the Tea Board prepared two plans for intensive cultivation and replanting. Bangladesh Tea Research Institute BTRI, the scientific wing of the Tea Board, also brought out several high yielding clonal varieties of distinct character and quality (Mondal et al., 2004; Muthaiya et al., 2013 and Li et al., 2015).

By 1979, British experts had devised a plan to revive Bangladesh's embattled tea sector. While there was already a scheme in place for the intense cultivation and replanting of tea at this point, the most significant effort began in 1983–84 and went into action in 1985–86. Throughout this time, CTC (Crush-Tear-Curl) teas gained popularity in Bangladesh among domestic and foreign consumers because to its ability to produce more robust faster-brewing liquor with more cuppage. Almost 99 percent of the tea types produced in Bangladesh now are CTC teas (Islam et al., 2021 and Hossain, 2015).

Bangladesh Tea Board

Bangladesh Tea Board is a statutory body. The then Pakistan Tea Board was formed on February 22, 1951 under the Pakistan Tea Act-1950. Father of the Nation Bangabandhu Sheikh Mujibur Rahman served as the chairman of the then Tea Board from 04 June 1957 to 23 October 1958. On August 8, 1959, the Tea Ordinance 1959 was issued to regulate the Tea Board by repealing the Pakistan Tea Act-1950.

In 1977, Tea Ordinance-1959 was repealed and Tea Ordinance-1977 was issued and Bangladesh Tea Board was established under this Ordinance. On August 1, 2016, through a gazette, the Government repealed the Tea Ordinance-1977 and promulgated the Tea Act, 2016. Bangladesh Tea Board is being managed as per the Tea Act, 2016. There are two institutions under Bangladesh Tea Board are: Bangladesh Tea Research Institute (BTRI) and Project Development Unit (PDU).

Regulatory Body of Bangladesh Tea Board

Bangladesh Tea Board comprises of following members:

1. Honorable Chairman, Bangladesh Tea Board
2. Member (Research & Development) and Member (Finance & Trade)
3. Divisional Commissioner of Chittagong, Sylhet and Rangpur
4. Joint secretary, Ministry of Commerce

5. Joint secretary, Ministry of Land
6. Chief Forest Conservator, Forest Department
7. Chairman, Bangladesh Tea Association
8. Chairman, Tea Traders Association of Bangladesh
9. One (01) Member from Tea Brokers, Appointed by the Government of Bangladesh
10. Two (02) Members from Tea Planters, Appointed by the Government of Bangladesh

Functions of Bangladesh Tea Board

The main activities of Bangladesh Tea Board are development of tea industry and taking all measures to increase production, marketing and export of tea, establishment of new tea plantations and rehabilitation of abandoned tea plantations, imposition of sub-tax on tea produced in Bangladesh and taking measures in other related matters and overall tea Regulating the activities of industry. The vision and mission of Bangladesh Tea Board are following**:**

Vision: To grow more quality tea to serve greater demand; i.e. grow for export after meeting our local demand.
Mission: To maximize tea production & quality by utilizing whole tea cultivable land in Bangladesh, motivating small holding tea cultivation and exporting tea after meeting our local demand.

According to Tea Act, 2016 the functions of the Board are given below:

i. Adopting suitable actions to promote the overall development of the tea industry;
ii. Implementing strategies to enhance tea yield;
iii. Control and management of import, export and sale of tea;
iv. Evaluating the quality of different types of tea and taking measures to improve the quality of tea;
v. Taking arrangements for tea tasting training;
vi. Collection of information from tea producers, manufacturers or traders or any other person associated with tea and tea industry;
vii. To undertake and conduct scientific, technical and economically viable research activities on tea cultivation technology as well as to establish and maintain demonstration fields for increasing the production and quality of tea.;
viii. Aid in the control of insects and pests harmful to tea;
ix. Providing necessary support for the growth of cooperative activities among small garden tea producers;
x. Training arrangements for persons engaged in tea cultivation and garden management and employees working under the control of the Board;
xi. Undertake scientific, technical and economic research activities and provide necessary assistance in maintenance of demonstration farms and production centers for increasing production of tea and other cash crops.;
xii. Collection and conservation of information from tea producers, manufacturers or traders or any other person associated with tea for the betterment of tea industry;
xiii. Registration of tea estates and factories as well as licensing of estate owners, tea manufacturers, exporters, blenders, bidders, brokers, tea waste dealers and wholesalers with retailers;
xiv. To take charge of any business or to acquire, take over or operate any business establishment as directed by the Government;
xv. Establishment of new plantations including taking over and rehabilitating abandoned plantations as per the plan approved by the Government and generally providing necessary support to the existing plantations to increase production;
xvi. Taking appropriate measures to ensure utilization of surplus land of tea estates;

xvii. Adoption of welfare measures for plantation workers and employees and

xviii. To take appropriate measures and undertake other activities as directed by the Government from time to time for the development of tea industry in Bangladesh (Tea Act, 2016).

Present Status of Bangladesh Tea

Table 01 represents tea production (million kg), consumption (million kg), export (million kg) and export value from 1947 to 2023 (BTB, 2023; Mondal et al., 2021; Ahmad et al., 2013; Arefin and Hossain 2022). Tea exports have dropped to 96.64% during the past 43 years (from 1980 to 2023), despite a 460.55% improvement in production from 1947 to 2023. In 1980, the share of tea exported was 77.37% of the entire production; by 2023, however, currently it was just 1.01%. The primary cause was the high rate of quick consumption, which increased as the population and tea production. A significant correlation was found to exist between the production, consumption, and export of tea. The correlation coefficient or r value, between tea production and consumption is 0.95, which indicates a significant positive relationship and shows that our consumption of tea is rising daily in tandem with production. However, a significant negative correlation (r value = -0.74) was identified between tea consumption and export, indicating that our intensive tea drinking habit has over time led to a decline in export.

Table 1. Tea Production (Million Kg), Consumption (Million Kg), Export (Million Kg) and Export Value (M. BDT) from 1947-2023 in Bangladesh.

Year	Production (Million Kg)	Consumption (Million Kg)	Export (Million Kg)	Export Value (M. BDT)
1947	18.36	-	-	-
1970	28.00	5.77	-	-
1980	40.04	9.06	30.98	-
1990	45.89	14.21	26.45	-
2001	53.15	36.95	12.92	894.99
2002	53.62	41.5	13.65	939.93
2003	58.3	37.44	12.18	915.07
2004	56	43.33	13.11	934.04
2005	60.14	43.3	9.01	742.62
2006	53.41	40.51	4.79	469.59
2007	58.19	46.27	10.56	899.01
2008	58.66	52.12	8.39	976.95
2009	59.99	53.74	3.16	433.5
2010	60.04	57.63	0.91	176.68
2011	59.13	58.5	1.48	213.51
2012	62.52	61.19	1.56	222.28
2013	66.26	64	0.54	133.04
2014	63.88	67.17	2.66	281.72
2015	67.38	77.57	0.54	105.13
2016	85.05	81.64	0.62	140.56
2017	78.95	85.93	2.56	377.29
2018	82.13	90.45	0.65	203.93
2019	96.07	95.2	0.6	194.26
2020	86.39	91.97 (calculated)	2.17	347.14
2021	96.506	95.2 (calculated)	0.68	180.57
2022	93.829	98.43 (calculated)	0.78	196.31
2023	102.918	101.65 (calculated)	1.04	272.52

Tea production, consumption and export of Bangladesh of last two decades were presented in Fig. 1. The production and consumption were found to be upward trending while export was found declining over time. The regression equation of tea production, consumption and export were $y = 0.1231x^2 - 0.7736x + 56.252$, $y = 0.0554x^2 + 1.8972x + 32.98$ and $y = 0.0491x^2 - 1.782x + 16.696$ respectively. From the regression equation of tea production, it can be calculated that the production will be 113.85 million kg by 2025 and 143.83 million kg by 2030.

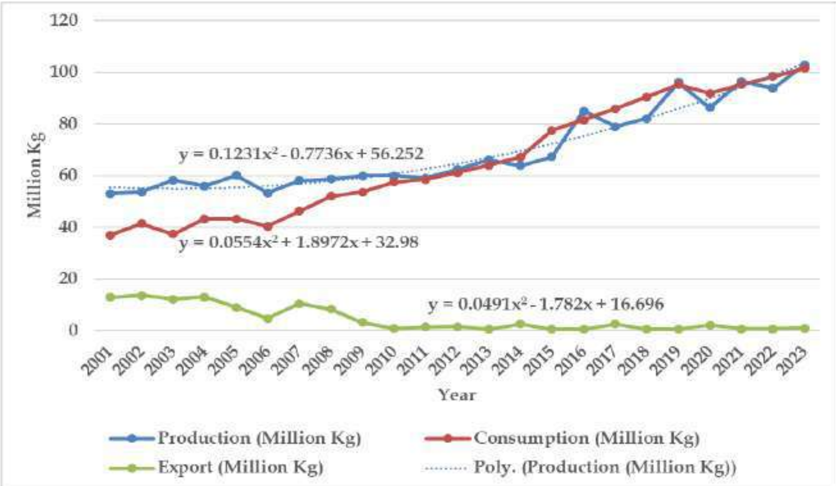

Fig. 1. Tea production, consumption and export of Tea from 2001-2023 with regression equation

In Bangladesh, there are 167 tea estates in Moulvibazar, Habiganj, Sylhet, Chattogram, Rangamati, Panchagarh, Thakurgaon and khagrachari district. District wise number of tea estates was provided in Fig. 02. At present, Moulvibazar district (90) has the highest number of tea gardens in the country. Besides, there are 25 tea gardens in Habiganj, district, 22 in Chattogram, 19 in Sylhet, 8 in Panchagarh, 2 in Rangamati, 1 in Thakurgaon and 1 tea garden is situated in khagrachari district. Recently, the highest tea production was recorded in the history of 184 years of Bangladesh tea industry. A total of 102.92 million kg of tea has been produced in 2023 from 168 tea gardens and small scale tea gardens in the country, surpassing all previous records of tea production.

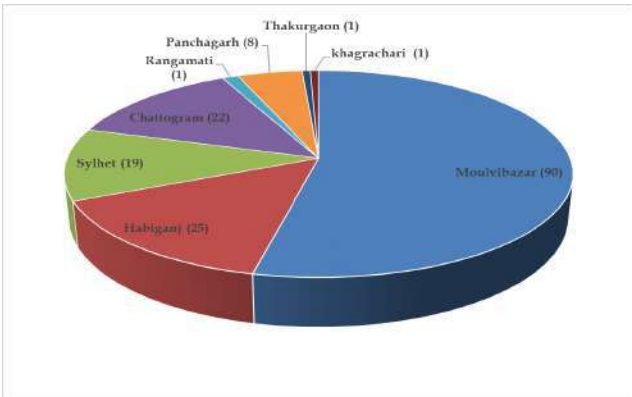

Fig. 2. Major tea growing districts with number of tea garden in Bangladesh

Tea cultivation in Northern Region of Bangladesh

Panchagarh is the pioneer district of small-scale tea cultivation in the northern region of Bangladesh. After Greater Chittagong and Sylhet, North Bengal is already known as the third tea region of the country. Tea cultivation in northern region is the brainchild of Hon'ble Prime Minister. In 1996, the then and current Prime Minister Sheikh Hasina visited Panchagarh district and thought about the potential of tea cultivation. According to the command, tea cultivation was carried out experimentally under supervision of the Deputy Commissioner of that time Mr. Md. Rabiul Islam. In 1999, tea cultivation plan was adopted in North Bengal. In October 1999, an expert team of Bangladesh Tea Board conducted a survey in Panchagarh and Thakurgaon districts to ascertain the potential of tea cultivation. The survey committee determined the potential for tea cultivation on about 40,000 acres of land in Panchagarh and Thakurgaon districts. Later in 2000 Tetulia Tea Company Limited (TTCL, 2000) and Kazi & Kazi Tea Garden started commercial tea cultivation. At that time, 6-7 small farmers started tea cultivation with the advice of Bangladesh Tea Board officials. Since then, tea cultivation in North Bengal gradually gained wide spread, trust and popularity. The overall scenario of tea (both tea cultivated land and made tea production) in North Bengal from the beginning to last year (2023) is presented through Fig. 3 and Fig. 4. A record amount of 17.93 million kg of tea has been added to the national production in 2023 from the plain tea plantations and small scale plantations in the northern region which is 17.42% of total national production (Barua, 2024; Mamun, 2022; Ahmed, 2015; Ahmed, 2014)

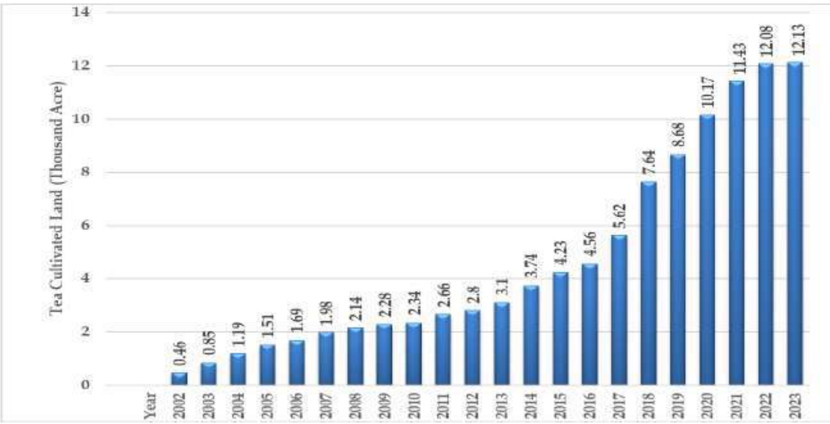

Fig. 3. Tea cultivation (thousand acre) in Northern region of Bangladesh

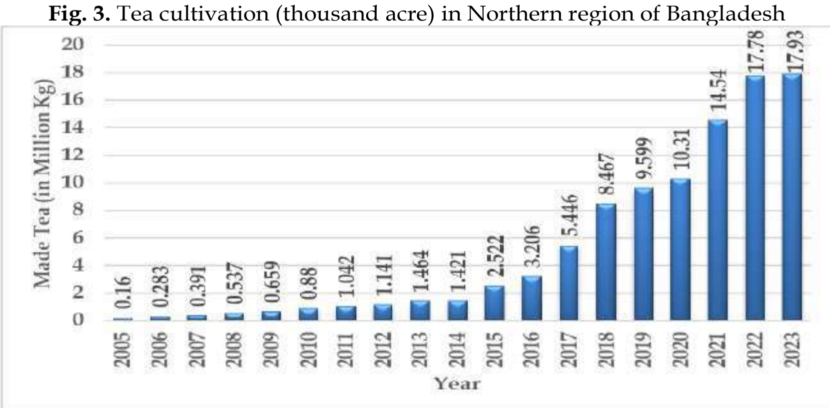

Fig. 4. Made Tea production (million Kg) in Northern region of Bangladesh

Role of improved planting materials in upgrading production and quality of tea industry

In comparison with other tea-growing nations around the world, our current production per hectare is rather low (Aziz et al., 2020). Approximately 35% of our tea producing area is made up of older and less productive seedling plants that are over 60 years old, which is one of the main causes of lower production of Bangladesh (PDU, 2015). Tea exports diminish as a result of rising domestic consumption decreasing exportable surplus and a slow pace of production growth. The tea sector has experienced a minimal economic return due to unfavorable weather circumstances and rising production costs. Under these conditions, the industry must expand in new areas and replant existing ones using higher-yielding and better-quality planting materials (Dutta and Alam, 2001). Therefore, by providing long-term employment opportunities for marginal landowners and the large landless population, as well as by optimizing the commercial use of fallow land in a land-hungry nation like Bangladesh, the development and cultivation of new, high-yielding tea varieties can contribute to the eradication of poverty (Hossain et al., 2017).

Superior planting materials with desired traits can be developed by hybridizing within existing genetic diversity or by introducing new genetic variability through other non-conventional breeding techniques such polyploidy, mutation, and tissue culture. The conventional methods of tea crop improvement are i) introduction, ii) selection, and ii) hybridization. Since its founding, BTRI has prioritized clonal selection and hybridization programs with the goal of developing planting materials with high yield and quality potential. The institution has provided 23 Vegetative Clones and 5 Bi-clone Seedling (Seed Stock) in the BT-series to the industry so far, as a result of these researches (Table 02).

Table 2. BTRI released Clones and Bi-Clone Seedlings with their yield and quality

Clone/ Bi-Clone Seedling	Release Year	Yield (Kg/ha) At Mature Stage	Quality*	Category**
BT1	1966	3298	AA	Standard
BT2	1975	3627	AA	Standard
BT3	1975	3431	AA	Standard
BT4	1981	2581	E	Quality
BT5	1987	2811	AA	Standard
BT6	1987	2916	E	Quality
BT7	1991	2790	AA	Standard
BT8	1992	3316	AA	Standard
BT9	1994	3784	AA	Standard
BT10	1995	4600	AA	Yield
BT11	1999	3713	AA	Standard
BT12	2000	4018	AA	Yield
BT13	2000	3203	AA	Standard
BT14	2002	3450	AA	Standard
BT15	2002	3735	E	Quality
BT16	2005	3604	AA	Standard
BT17	2006	3897	AA	Standard
BT18	2010	3777	AA	Standard
BT19	2016	3877	AA*F	Standard
BT20	2016	3685	E	Quality
BT21	2018	3447	AA	Standard
BT22	2021	3304.15	E	Quality
BT23	2021	3341.75	AA	Standard (DT)
BTS1	1985	3217	AA	---------
BTS2	1985	3110	AA	---------
BTS3	2001	3381	AA	---------
BTS4	2001	3303	AA	---------
BTS5	2019	3709.9	AA	--------

Note:
* Quality category based on Tea Quality score:

i. E = Excellent (≤34 out of 50)
ii. AA = Above Average (32≤ to <34 out of 50)
iii. A = Average (30≤ to <32 out of 50)
iv. BA = Below Average (<30 out of 50) (Bezbaruah and Dutta, 1977)

** Clonal category based on Yield Quality:

i. Yield clone: Yield of ≥ 4000 Kg/ha with Above average or Average Cup Quality,
ii. Standard clone: Yield of 3000 - <4000 Kg/ha with Above Average or Average Cup Quality,
iii. Quality clone: Yield of 2500 - <3000 Kg/ha with Excellent Cup Quality (Amma, 1974; Bezbaruah and Dutta, 1977; Wachira, 1994)

The first vegetative clone of BTRI, named Bangladesh Tea 1 (BT1), was developed in 1966. The tea industry suffered greatly during the 1971 liberation war and production was significantly impacted. The usage of BTRI-released clones was steadily extended after 1971 in order to boost up Bangladesh Tea yield and quality. From the Fig. 5, it was observed that the clonal adaptation and tea production was increased from early 1980. According to a research conducted in 1994, 90% of the whole tea area was occupies by seedlings, with the remaining clones being mostly garden clones and a small amount of imported clones (Alam, 1994). A positive change in the clonal plantation was seen in the subsequent 2001 investigation. That research examined 58.72% of the entire tea area, of which 21.02% were pure clonal plantations, 3.6% were bi- and polyclonal seedlings and the remaining plantations were general seedlings (Alam, 2002). According to a different study, the average area of entire tea plantation is 54.34% for seedlings and 41.64% for clones (Boonerjee, 2016). The Statistics Division of BTRI recently carried out an experiment in which the adoption rates of TV and BT clones in the 144 tea estates spread across several valleys were investigated. The experiment revealed that clonal plantations with an average productivity of 1607.48 kg/ha, occupied around 41.64% of the total tea areas of the seven valleys. The percentage of Indian TV clones and Bangladeshi clones usage was about 40.20% and 45.05%, respectively (BTRI, 2020). Furthermore, a noteworthy relationship has been noticed between tea production and the rate of clonal adaptability in Bangladesh. There is a significant positive association between tea production and the rate of clonal adaptability, as indicated by the correlation coefficient (r = +0.98).

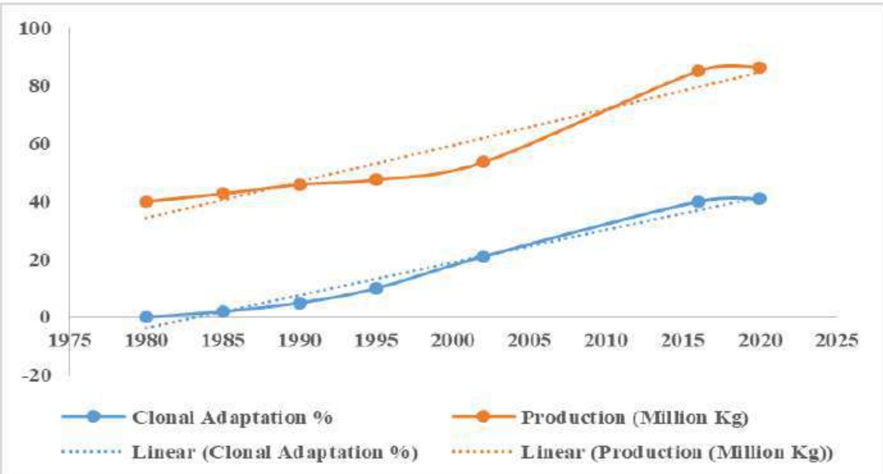

Fig 5. Increasing Rate of Clonal Adaptation and Tea Production of Bangladesh (1980-2020)

Some Recent activities of Bangladesh Tea Board in Research, Development and Finance of Bangladesh Tea Industry

i. Research and sustainable technologies were developed by BTRI for the betterment of tea industry such as innovation and application of organic fertilizer and vermicompost production technology, determination of poultry manure ingredients, development of high yielding, quality and drought tolerant varieties of tea, determining ideal planting technique for tea plantations in Bangladesh, controlling pests of tea (such as *Helopeltis*, red spider, nematodes etc.), developing Integrated Pest Management (IPM) strategies, determination of pesticide residues in prepared tea, integrated management in suppression of tea diseases (horsehair blight, red rust, gall, charcoal stump rot, root rot diseases etc), BTRI developed techniques for determination of biochemical properties of TF, TR and other components of free clones and forecasting of annual production of tea crops.

ii. On the birth centenary of Bangabandhu Sheikh Mujibur Rahman, the greatest Bengali of all time and the Father of the Nation, under the initiative of the Ministry of Agriculture, Bangladesh Agricultural Research Council (BARC) has published '100 Agricultural Technology Atlas'. The '100 Agricultural Technology Atlas' was unveiled by the Honorable Prime Minister of the People's Republic of Bangladesh, Sheikh Hasina, MP. The book featured 4 technologies developed by Bangladesh Tea Research Institute such as ‘Improved variety clone BT2’, ‘Seed variety BTS1’, ‘IPM technology for sustainable tea production’ and ‘Use of green crops to improve soil quality’.

iii. Tea industry stakeholders are regularly informed about institute research findings and sustainable technologies developed. Technology transfer activities are conducted through advisory tours, research sub-committees, annual courses, seminars, workshops, annual reports, journals, circulars, notifications, letters, pamphlets, tea tasting sessions, emails, websites, electronic media and mobile apps. Recently Bangladesh Tea Board has developed several mobile apps named ‘Duti Pata Ekti Kuri’, ‘Cha Seba’, ‘Somotoler Cha Shilpo’, ‘Bangladesh Tea Industry’, ‘Tea soft’ for the successful technology transfer and for the betterment of tea planters.

iv. According to the Tea Act-2016, inspection and evaluation of the development activities of tea plantations in Bangladesh, inspection of tea factory, on-site inspection and report preparation of tea plantation expansion at the rate of 2.5% have been conducted by Project Development Unit (PDU), an organ of the Bangladesh Tea Board. Besides, Hands-on training workshops for skill development of tea estate managers and timely training workshops for Tila Babu of tea estates and small tea farmers of North Bengal have organized for quality tea production. Professional Diploma in Tea Management (PDTM) for Tea Estate Managers and Assistant Managers and Tea Production Course (TPC) for skill development of gardeners have organized through Management Training Center of PDU (PDU, 2023). Bangladesh Tea Research institute (BTRI) organizes 06 days long 'BTRI Annual Course' every year for tea plantation management and manual training in scientific method for tea growers. 965 tea planters have been trained so far with great success (PDU). In 2022, for the first time, the 'Tea Testing and Quality Control' course was launched by Bangladesh Tea Board.

v. 'Camellia Khola Akash School' has been launched at union level without walls and roof to deliver training services to the doorsteps of the small tea farmers in the northern region, keeping the slogan 'Improved knowledge, improved tea' in front. Under this programme, more than 100 hands-on training workshops on “Scientific Tea Plantation Management” have been organized for more than 5,000 small tea growers at the union level.

vi. The short term (2016-2020) target of "Development Roadmap: Bangladesh Tea Industry" for tea industry development has already been implemented. 100% of short term target achieved. Besides, the implementation of the medium term (2021-2025) and long term (2026-2030) targets is ongoing. Incentive of Tk 120.00 crore by Bangladesh Bank was financed at Bangladesh tea industry due to Corona epidemic. Tea Act, 2016 was published as Gazette in schedule of Mobile Courts Act, 2009 for the development of tea industry.

vii. In order to strengthen research on tea in Chittagong region, 'Bangladesh Tea Research Institute Region Based Tea Research Farm, Banshkhali, Chittagong' was established. A 'Modern Soil Science Laboratory' was established for the first time at BTRI Fatikchari sub-station to analyze soil samples of tea plantations in Chittagong region. Permanent office of Tea Board at Lalmonirhat was also established to strengthen the activity of Bangladesh Tea Board in Northern Region of Bangladesh.

viii. On March 15, 2021, Chittagong Tea Auction Center launched an online tea auction program on an experimental basis. On December 8, 2017, the country's second tea auction center was launched at Srimangal, Moulvibazar. The country's third tea auction center was launched in Panchagarh in a bid to ensure fair price of tea from bought tea leaves. 'Online Tea License System' was launched for receiving tea license applications online and issuing licenses. The auction price of tea has been set in 'Base Price' line to control the decline in tea prices in recent times for being compatible with the cost of production.

ix. There is no alternative to export of tea to ensure fair selling price against the bumper yield of tea in the country. Bangladesh Tea Board is working extensively to bring back the lost glory days of tea export. As part of this, recently Bangladesh Tea Board has already exported high-quality orthodox tea to a well-known organization called London Tea Exchange. Bangladesh Tea Board participated in 'Gulfood 2024' held on February 19-23, 2024 in Dubai, United Arab Emirates with the aim of introducing the country's tea industry to the international market and increasing tea exports.

x. Every year numerous planting materials, irrigation equipment, plucking machines, besides other technologies are distributed among the tea stakeholders at minimal cost and even free of cost to encourage tea growers to adopt modern technology.

Target of Development: Projection upto 2030

A 'Roadmap for Development: Bangladesh Tea Industry' or 'Unnoyoner Pathonoksha: Bangladesh Cha Shilpo' was developed including 11 action strategies for the development of Bangladesh tea industry; which was approved by the Cabinet Division on January 31, 2017 (BTB, 2016). As part of the Bangladesh Tea Board's plan, it is projected that overall tea output would reach 140 million kg by 2025, meeting both domestic consumption and resuming foreign tea exports (Ahmed and Ahmed, 2015). Intensive plantations using improved clones and seed stocks are one of the greatest ways to assist tea companies to reach their objectives. However, because additional land is not available for the expansion of tea production, the plantation areas that are now existing must be upgraded with high-yielding, high-quality clones as well as superior seed stock. It is possible to move tea production toward the intended target and keep the existing tea estates financially viable by filling up vacant areas and planting new, better clones and seedstock in previously uprooted regions. Some major strategies of action plan (for developing tea estates, for less developed/ sick tea estates, for small holding tea, for BTRI and for PDU) for increasing productivity and quality of Bangladesh Tea are given in Table 3 (a,b,c,d and e).

Table 3.a. Some major action plans for 'Developing Tea Estates' to increase productivity and quality by 2030

Plans	2016-2025		2016-2030	
	Activities	Result	Activities	Result
Infilling of tea vacant area by 165 lac saplings	Infilling of vacant area by 140 lac tea saplings to reduce tea vacancy 7.00%	Production will increase 3.2 million kg	Infilling of vacant area by total 140+25=165 lac tea saplings to reduce tea vacancy 5.00%	Production will increase 4.8 million kg
Replanting/ Block Infilling of total 10,000 ha	Replanting/ Block Infilling of total 8,274 ha	Production will increase 20 million kg	Replanting/ Block Infilling of total 8,274+1726=10,000 ha	Production will increase 20+10=30 million kg
Extension of Tea in new 5,868 ha area	Tea Extension in new 3,868 ha area	Production will increase 10 million kg	Tea Extension in total 3,868+2000=5,868 ha area	Production will increase 10+05=15 million kg

Table 3.b. Some major action plans for 'Less Developed/ Sick Tea Estates' to increase productivity and quality by 2030

Plans	2016-2025		2016-2030	
	Activities	Result	Activities	Result
Infilling of tea vacant area by 90 lac saplings	Infilling of vacant area by 70 lac tea saplings to reduce tea vacancy 7.00%	Production will increase 0.18 million kg	Infilling of vacant area by total 70+20=90 lac tea saplings to reduce tea vacancy 5.00%	Production will increase 2.7 million kg
Replanting/ Block Infilling of total 320 ha	Replanting/ Block Infilling of total 300 ha	Production will increase 0.30 million kg	Replanting/ Block Infilling of total 300+20=320 ha	Production will increase 0.30+0.02=0.32 million kg
Extension of Tea in new 1,000 ha area	Tea Extension in new 800 ha area	Production will increase 1.92 million kg	Tea Extension in total 800+200=1,000 ha area	Production will increase 1.92+0.48=2.40 million kg

Table 3.c. Some major action plans for 'Small Holding Tea' to increase productivity and quality by 2030

Plans	2016-2025		2016-2030	
	Activities	Result	Activities	Result
Extension of Tea in new 4,000 ha area	Tea Extension in new 3500 ha area	Production will increase 8.4 million kg	Tea Extension in total 3500+500=4,000 ha area	Production will increase 8.4+1.2=9.60 million kg
Establishment of Bought Leaf Factory	New 4 Bought Leaf Factories will be established	8.4 million kg made tea will be manufactured by 4 factories	5 (4+1) Bought Leaf Factories will be established	9.6 million kg made tea will be manufactured by 5 factories

Table 3.d. Some major action plans for enhancing research activities in 'Bangladesh Tea Research Institute (BTRI)' by 2030

Plans	2016-2025	2016-2030
Strengthening of BTRI substations	Strengthening of BTRI substations by funding of 96 lac tk. to disseminate newly developed technologies to the end users	Strengthening of BTRI substations by funding of 126 lac tk. to disseminate newly developed technologies to the end users
Distribution of improved planting materials and other technologies	Funding of 23 lac tk. for the Distribution of improved planting materials and other technologies	Funding of 30 lac tk. for the Distribution of improved planting materials and other technologies
Crop improvement programme	Funding of 8.7 lac tk. for crop improvement programme	Funding of 10.7 lac tk. for crop improvement programme
Tissue culture lab	Adopt the technology for tissue culture for successful root and shoot regeneration	Establishment of tissue culture lab with proper technology for rapid multiplication of tea saplings.
Integrated pest and disease management technology	Funding of 96.2 lac tk. for Integrated pest and disease management technology to control pest and disease of tea gardens	Funding of 103.45 lac tk. for Integrated pest and disease management technology to control pest and disease of tea gardens

Table 3.e. Some major action plans for providing training facilities by 'Project Development Unit (PDU) by 2030

Plans	2016-2025	2016-2030
Postgraduate Diploma Course	Skilled human resource development by Postgraduate Diploma Course of 480 personnel	Skilled human resource development by Postgraduate Diploma Course of 720 personnel
Tea production course	Providing training to 120 tea estate stuffs by Tea production course	Providing training to 180 tea estate stuffs by Tea production

Conclusion

Tea industry of Bangladesh is a significant labor-intensive, agro-based sector focused on exports. It generates employment, regulates commerce and provides exports, all of which are extremely important to our economy. Currently, however, the tea sector in Bangladesh is dealing with a number of difficulties. Due to local consumption and other considerations, Bangladesh tea is nearly extinct from the traditional worldwide markets. We used to be a tea exporting country, but now we import tea since our consumption of tea exceeds our production. It is highly advised to develop a thorough long-term development strategy for sustainable tea business based on meticulous, scientific, and rigorous study in order to address this issue. Efficient technology transfer system and its proper execution in the field are equally important. The tea industry needs to harness full potential of the innovated technologies developed by BTRI as well as Bangladesh Tea Board to overcome the constraints confronting our tea industry.

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ANALYZING THE EFFECTIVENESS OF NATIONAL ENVIRONMENT POLICY TO REDUCE PESTICIDE POLLUTION IN THE TEA SECTOR

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and AKM Rafikul Hoque[3]

Abstract

Tea is a popular health beverage in the world, produced from the leaves of the evergreen shrub *Camellia sinensis*. Tea is a major cash crop and an export commodity in Bangladesh. It's estimated that people drink around three billion cups every day. However, tea plantations are threatened by pests, and planters/farmers must find effective ways to stop them. Chemical pesticides are used widely in agriculture. They play a significant role in many types of farming, including tea plantations. However, due to the potential environmental and health risks associated with their use, pesticides are beginning to alarm consumers and producers alike. The study was conducted to analyze the effectiveness of national environment policy to reduce pesticide pollution in the tea sector. For the survey, relevant data were collected from secondary and primary sources such as books, journals, newspapers, and websites. Both quantitative and qualitative information were used to conduct the study. Data were also collected through questionnaires, interviews, Focus Group Discussions (FGD), and online surveys. Most of the respondents were planters (62.20%) followed by government officials (29.70%). The educational level of respondents consists of SSC to PhD. Most respondents belong to the Masters category (66.20%), followed by the Bachelor category (24.30%). The result revealed that most respondents are 41-50 yrs (32.40%), followed by 31-40 yrs (29.70%). Results revealed that most respondents (47.30%) replied that all the measures (Chemical, Biological, Cultural, Plant Extracts, Yellow Sticky Traps, etc.) were taken to control tea pests. 70.30% of respondents agreed that the environment is polluted due to the indiscriminate use of pesticides. 60.80% of respondents have sound knowledge about environmental pollution due to the indiscriminate use of pesticides in the tea garden. 67.60% of respondents knew the National Environment Policy 2018 and 64.90% implemented it in their tea gardens, which is appreciated. Most of the respondents replied that Joddha (Dinotefuran), ShengLi (Emamectin Benzoate + Thiamethoxam), Calypso (Thiacloprid), Admire (Imidacloprid), Magistar (Fenzaquin) and Automida (Acephate + Imidacloprid) used in their tea gardens. However, 90.50% knew the integrated pest management (IPM) techniques. Most respondents (41.90%) used bio-pesticides as the integrated pest management (IPM) technique, which is much appreciated. However, the rest of the respondents used botanicals, yellow sticky traps, solar light traps, termite queen collections, bracon parasitoids, etc. It was found that 100% of respondents did not use dirty dozen chemicals such as DDT, Heptachlor, Dieldrin, etc. in their tea garden, which is much appreciated. 59.50% of respondents agreed that awareness building, training & motivation, the introduction of IPM in the tea gardens, organic farming, punishment, and finally, updating the policy could make environment policy more effective in the tea sector.

Keywords: Agriculture, Environment Policy, Pesticide Pollution, Policy evaluation, Tea Sector, Organic Farming, IPM, Bangladesh

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Introduction

On a global scale, agriculture holds immense importance. Bangladesh relies predominantly on agriculture, which plays a pivotal role in driving its swift economic progress. The agricultural sector is indispensable to the nation's overarching economic development. Crops, animal husbandry, forestry, and fisheries account for 41.74% of the nation's GDP and employ roughly 41% of the working force (BBS, 2017). Pesticides are one of the most important tools for protecting crops from insects and disease infestation. Pesticides have the potential to seep into groundwater and surface water bodies via runoff and infiltration, leading to water pollution and diminishing the availability of clean water. Additionally, pesticides may infiltrate soils and groundwater, thereby compromising the safety of drinking water. Furthermore, airborne pesticides from spraying activities can spread and contaminate the air. These chemicals can also taint soil, turf, water sources, and vegetation. Beyond their intended targets of insects and weeds, pesticides threaten other organisms, including fish, birds, beneficial insects, and non-target plants.

Tea is a popular health beverage in the world, produced from the leaves of the evergreen shrub *Camellia sinensis.* Tea is a major cash crop and an export commodity in Bangladesh. Now, there are 168 tea estates and more than 8,000 small tea gardens having about 66,000 hectares of tea plantation producing about 102.918 million kg of finished tea per annum with an average yield of about 1,700 kg per hectare in Bangladesh, contributing 1% of GDP (BTB, 2023). The tea plant is subjected to the attack of several insects, mites & nematodes. In the world tea, 1034 species of arthropods (insects & mites) and 82 species of nematodes are associated with tea plants (Chen and Chen, 1989). Among them, 25 species of insects, 4 species of mites and 10 species of nematodes are recorded from Bangladesh (Ahmed, 2005; Mamun and Ahmed, 2011). About 10-15% of its crop could be lost by various pests, particularly insects, mites and nematodes (Sana, 1989). To combat these pests, different groups of pesticides like organochlorine, organophosphate, pyrethroids, carbamates and some unclassified groups have been used in the tea fields since 1960. Chemical pesticides have been used for a long time but have serious drawbacks, such as direct toxicity to beneficial insects, fishes and human beings; pesticide-induced resistance, health hazards and increased environmental social costs and undesirable pesticide residue in made tea (Mamun, 2019). To rid tea gardens of weeds, producers use the harmful chemical glyphosate, mainly under the brand name Roundup, as a herbicide; the chemical is banned in 33 countries due to its adverse impacts on biodiversity (Kudsk and Mathiassen, 2020). Despite concern among agriculturists and environmentalists, the government has yet to take any initiative to control the use of harmful chemicals (Parvin, 2024).

A good environment is essential for a good life. Environmental pollution is one of the most critical burning issues in Bangladesh. It includes air, water and soil pollution. Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh has enacted National Environment Policy-2018. The National Environment Policy envisaged environment conservation, pollution control, biodiversity conservation, and mitigation of the adverse effects of climate change to ensure sustainable development. Agriculture is one of the prime areas/sectors of that environmental policy. Among the various specific measures, using natural bio-fertilizers and biopesticides is encouraged instead of applying agrochemicals and artificial materials, which should be controlled for adverse environmental impact. It's time to reduce pesticide pollution in the agriculture sector.

In the context of land degradation, declining productivity and quantity of agricultural land and, increasing population and ensuring food security in the context of addressing the adverse effects of climate change, the following policies should be followed to ensure sustainable agriculture:

- Organic farming should be given priority. In order to reduce agricultural pollution and soil pollution, the use of all types of chemical substances in agriculture should be controlled and the use of different types of bio-fertilizers and bio-pesticides should be encouraged.
- In order to preserve the biodiversity of the open reservoir, the use of harmful pesticides in the crop fields surrounding/inside the reservoir should be completely avoided. If necessary, environmentally friendly IPM should be introduced.
- The use of persistent organic pollutants and pesticides should be controlled.

The study aims to address and evaluate the National Environment Policy 2018 to reduce pesticide usage in the tea sector. The usage of pesticides on tea plantations in Bangladesh is largely governed by the Government of the People's Republic of Bangladesh under the Plant Protection Wing, Department of Agricultural Extension, Ministry of Agriculture and Bangladesh Tea Research Institute, an organ of Bangladesh Tea Board. However, different tea gardens or small tea growers use pesticides indiscriminately, ignoring the environmental policy. From the above point of view, very few studies have been conducted on this topic in Bangladesh. In Bangladesh, organic farming has started for various crops but is limited to the tea sector. The study will also focus on the organic farming issue in the tea sector to reduce pesticide pollution. This study will examine the effectiveness of environmental policy in reducing pesticide pollution in the tea sector. Additionally, the study may serve as a reference for future research in this area. Therefore, this study aims to assess the effectiveness of environmental policies in mitigating pesticide pollution within the tea sector.

Materials and Methods

The study was conducted to analyze the effectiveness of national environment policy to reduce pesticide pollution in the tea sector. For the survey, relevant data were collected from secondary and primary sources such as books, journals, newspapers, and websites. Both quantitative and qualitative information were used to conduct the study. Data were collected through questionnaires, interviews, Focus Group Discussion (FGD) and online surveys. Seventy-four (74) respondents of different age group & professions participated in the research. A total of 12 questions were supplied to the respondents of different groups. Analyzing the effectiveness of national environment policy to reduce pesticide pollution in the agriculture sector got special attention to the tea sector, which was done by a well-prepared questionnaire.

Results and Discussion

Seventy-four (74) respondents of different age groups & professions participated in the research (Table 1).

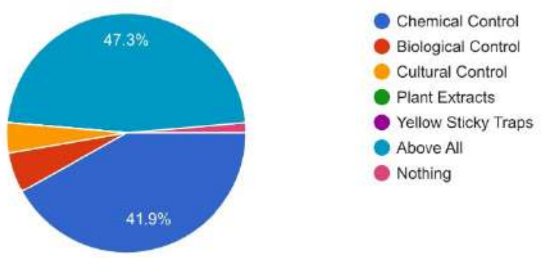
Table 1. Percent of respondents participated in the study.

Pameter	Percentage (%) of respondents
Age	
<30	6 (8.10)
30-40	22 (29.70)
41-50	24 (32.40)
51-60	17 (23.00)
>60	5 (6.80)
Gender	
Male	71 (95.90)
Female	3 (4.10)
Prefer not to say	0 (0.00)
Education	
PhD	5 (6.80)
Masters	49 (66.20)
Bachelor	18 (24.30)
HSC	1 (1.40)
SSC	1 (1.40)
None of above	0 (0.00)
Profession	
Government	12 (16.20)
NGO	2 (2.70)
Researcher	10 (13.50)
Planters	46 (62.20)
Farmers	0 (0.00)
Students	2 (2.70)
Others	2 (2.70)

A total of 12 questions were supplied to the respondents of different groups. Most of the respondents were planters (62.20%) followed by government officials (29.70%). The educational level of respondents consists of SSC to PhD. Most respondents belong to the Masters category (66.20%) followed by the Bachelor category (24.30%). People of different age groups participated in the study. The result revealed that most respondents are 41-50 yrs (32.40%) followed by 31-40 yrs (29.70%).

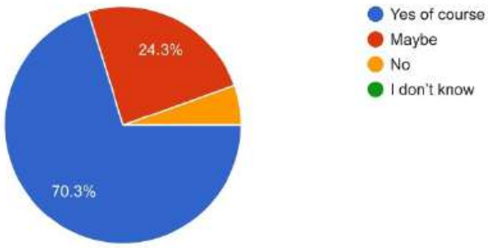
The question-wise analysis is described below:

1) What measures have you taken in the context of tea pest management?



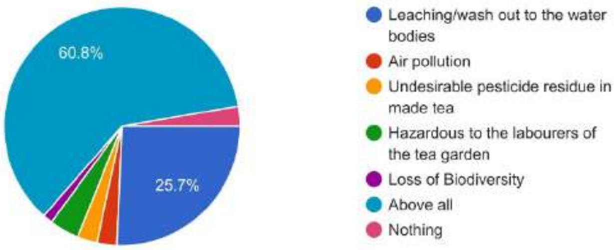
The first question was regarding the context of tea pest management. Most of the respondents (47.30) replied that all the measures had been taken to control tea pests. However, 41.90% of respondents answered that chemical control is the main measure in pest management in their tea garden.

2) Is there any environmental pollution due to the use of pesticide in tea gardens?



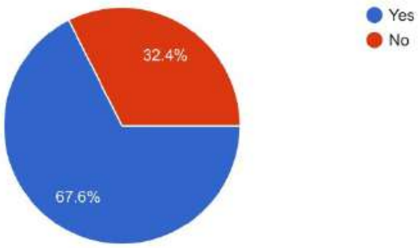
The second question was regarding the environmental pollution due to the use of pesticide. Most of the respondents (70.30%) agreed that the environment is polluted due to pesticide use.

3) How the applications of pesticides pollute the environment in tea gardens?



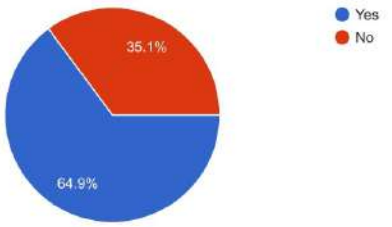
The third question was regarding the effect of pesticides on environmental pollution. Most of the respondents (60.80%) have a good idea of environmental pollution due to the indiscriminate use of pesticides in tea gardens. Secondly, about 25.70% of respondents agree to leaching/washing out the pesticide to the water bodies in their tea gardens.

4) Do you know about the National Environment Policy 2018?



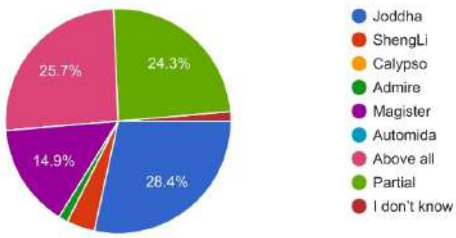
The fourth question was about the National Environment Policy 2018. Most respondents, i.e. 67.60%, knew the National Environment Policy 2018. Unfortunately, the rest of the 32.40% of respondents do not know about the policy. The government/Bangladesh Tea Board has to initiate awareness among the planters through training, seminars, workshops, etc.

5) Do you implement the policy in your tea garden?



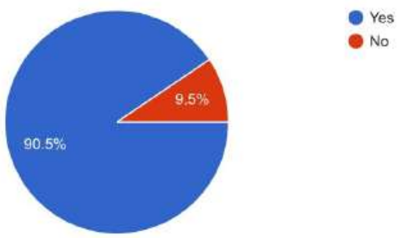
The fifth question was about implementing the national environment policy in the tea garden. 64.90% of respondents implement the national environment policy in their tea gardens, which is appreciated. Unfortunately, 35.10% of respondents do not implement the policy in their tea garden. The government/Bangladesh Tea Board has to take the necessary initiative to implement the policy in the tea gardens and small holding tea by imposing, motivation, training, seminar, workshop etc.

6) *What type of pesticides do you use in your tea garden?*



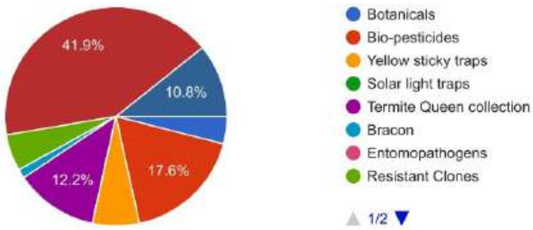
The sixth question was about the types of pesticides used in the tea garden. Most of the respondents replied Joddha (Dinotefuran), ShengLi (Emamectin Benzoate + Thiamethoxam), Calypso (Thiacloprid), Admire (Imidacloprid), Magistar (Fenzaquin) and Automida (Acephate + Imidacloprid) in their tea gardens. Joddha is the first choice of tea planters. Joddha (Dinotefuran) is an insecticide of the neonicotinoid class for control of insect pests such as aphids, whiteflies, thrips, leafhoppers, leafminers, sawflies, mole cricket, white grubs, lacebugs, billbugs, beetles, mealybugs, and cockroaches on leafy vegetables. However, In July 2013, the state of Oregon of US temporarily restricted the use of dinotefuran pending the results of an investigation into a large bee kill.

7) Do you know the Integrated Pest Management (IPM) techniques for safe tea production?



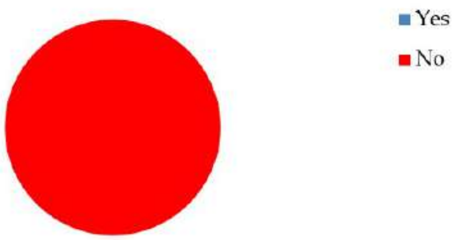
The seventh question was about integrated pest management (IPM) techniques. Most of the respondents (90.50%) knew the integrated pest management (IPM) strategies that is very much appreciated. However, only 9.50% of respondents do not know the integrated pest management (IPM) techniques. The government, Bangladesh Tea Board, and Bangladesh Tea Research Institute must take the necessary initiative to promote IPM in the tea gardens through motivation, training, seminars, workshops, etc.

8) *What measures you have taken for the control of pests & diseases rather than pesticides?*



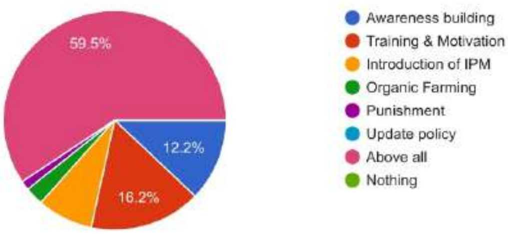
The eighth question was alternative measures taken for the control of pests & diseases rather than pesticides. Most of the respondents (41.90%) used bio-pesticides as the integrated pest management (IPM) technique, which is much appreciated. However, the rest of the respondents used Botanicals, yellow sticky traps, solar light traps, termite queen collections, bracon parasitoids etc. No respondents used entomopathogens. Entomopathogens, bacterial, viral or fungal, are pathogens that kill or seriously disable insects. They play a vital role in the natural regulation of insect pests. The government, Bangladesh Tea Board, and Bangladesh Tea Research Institute have to take the necessary initiative to promote IPM in the tea gardens and small tea holdings through motivation, training, seminars, workshops, etc.

9) *Have you used dirty dozen chemicals such as DDT, Heptachlor, Dieldrin etc. in your tea garden?*



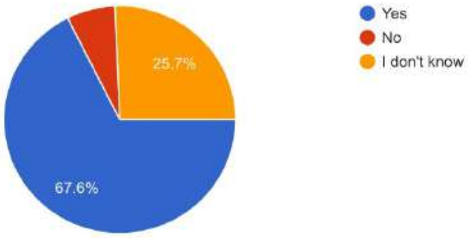
The ninth question was the use of dirty dozen chemicals such as DDT, Heptachlor, Dieldrin etc., in the tea garden. The survey found that 100% of respondents did not use dirty dozen chemicals such as DDT, Heptachlor, Dieldrin etc. in their tea garden, which is appreciated.

10) What can be done to make the environment policy more effective in the tea sector?



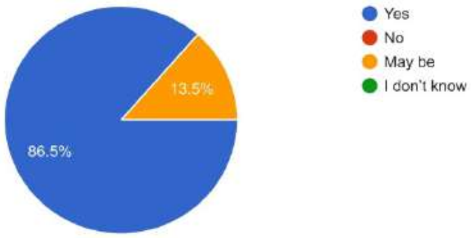
The tenth question was about making the environment policy more effective in the tea sector. The survey found that most respondents (59.50%) agreed to awareness building, training & motivation, the introduction of IPM in the tea gardens, organic farming, punishment and finally, updating the policy. They realize the importance of implementing an environmental policy in the tea garden.

11) *As no standard set of benchmark of pesticide presence in the soil or water & no punishment imposed in environment law/rules. Are these the limitations of the policy?*



The eleventh question was the limitations of the policy. From the survey, it is found that most of the respondents (67.60%) agreed that there is no standard set of benchmark of pesticide presence in the soil or water & no punishment imposed in environment law/rules. These are the important limitations of the policy.

12) Do you believe that Organic farming or IPM technique is the important tools to reduce the pesticide pollution in tea gardens?



The final question was regarding organic farming or IPM techniques to reduce the pesticide pollution in tea gardens. The survey found that most respondents, i.e. 86.50%, agreed that organic farming or the IPM technique is an important tool for reducing pesticide pollution in tea gardens.

Conclusion

Tea is an export-oriented commodity, hence in order to get around non-tariff trade barriers under World Trade Organisation (WTO) regimes, all necessary steps must be taken to maintain residues well below the Maximum Residue Limit (MRL). In general, Pre Harvest Index (PHI) of tea is to be considered 7-10 days as per Good Agricultural Practice (GAP). When necessary, only BTRI-recommended insecticides with permitted doses should be used. The safe harvest interval following pesticide application is seven days. For the safety of tea production and the preservation of biodiversity, every tea garden must abide by environmental policy. The most important component of chemical control measures under IPM strategy is the administration of pesticides in a need-based, prudent, and safe manner. Learning IPM techniques is necessary to save the environment by keeping an eye on crop health and preserving the possibility of natural bio-control before using chemical pesticides as a last resort. Pesticides will continue to be a crucial part of any plan for managing pests. The choice, application method, dosage, and timing of pesticides are vital factors in the efficient management of insect pests in tea.

Recommendations

The following suggestions and recommendations should be followed for sustainable pest management of tea in the context of environment policy:

- Organic farming or IPM techniques should be introduced in tea gardens.
- Awareness building among the planters should be created.

- Training & motivation should be done to implement environment policy in the tea garden.
- The policy may be updated by incorporating a standard set of benchmarks of pesticide presence in the soil or water & punishment imposed in environment law/rules.
- Monitoring the incidence of pests by assessing their populations in the field should be done.
- Economic Threshold Level (ETL) values of the pests should be followed.
- Appropriate control measures should be started at the beginning of the season.
- Use plant-origin biopesticides for biorational pest control
- Pesticides should be applied only when it is absolutely essential.
- Use only the pesticides which are recommended by Bangladesh Tea Research Institutes.
- Follow the recommended dosage and dilution rates stipulated for each pesticide. Spraying should be done with the approved pesticide only after plucking.
- Samples of tea may be analyzed for the residues of commonly used pesticides.

Collaboration between all the tea estates and the Rainforest Alliance should be needed for reducing pesticides in tea. In our country, tea estates belong to Duncan Brothers (Bangladesh) Ltd. and Kazi & Kazi Tea Estates strictly follow the rules and regulations of Rainforest Alliance. They are also certified by the Rainforest Alliance. The Alliance launched an integrated pest management (IPM) task force for the tea sector. Finally, it is concluded that awareness building, training & motivation, the introduction of IPM in the tea gardens, organic farming, punishment, and finally, updating the policy could make environment policy more effective in the tea sector.

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STANDARDIZATION OF QUALITY ASSESSMENT PARAMETERS OF BLACK TEA FOR ORGANOLEPTIC TASTING METHOD IN RESPECT OF BANGLADESH

Md. Ismail Hossain*

Abstract

Tea is one of the oldest beverages which is a completely non-alcoholic drink. Tea provides Bangladesh's entire domestic demand, which is of immense economic significance. Tea samples from 65 tea estates from different regions of Bangladesh as well as samples from different 'Valley Tea Tasting Session' were collected. Teas were evaluated for standardizing the quality assessment parameters during organoleptic tasting method in respect of Bangladesh. Organoleptic tea tasting can provide a comprehensive and direct measurement of the perceived intensity of target attributes, such as appearance, colour, aroma, taste and texture. The purpose of tea tasting is to describe and evaluate teas in the form of individual grade or as blended product. These include the appearance of the dry leaf, the infused leaf and characteristics of the liquor obtained by brewing the tea with boiling water. Tea tasting is performed by factory men for quality assessment, by brokers for a valuation price, by buyers to making choice or to buy tea and by blenders to maintain the standard of the blends. This paper will give a proper and ideal guideline for organoleptic tea tasting and its different quality assessment parameters including dry leaf appearances, infused leaf appearances and liquor characteristics.

Keywords: Tea, Organoleptic Tea Tasting, Dry Leaf Appearances, Infused Leaf Appearance, Liquor Characteristics.

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Introduction

Tea (*Camellia sinensis* (L.) Kuntze; Theaceae) is an important economic plant worldwide (Das et al., 2015), which has high economic value (Xue et al., 2013; Lou et al., 2014; Yang et al., 2015), which can be used to make tea (Kessenich and Higgs, 2010), a very popular drink (Hodgson et al., 2002; Hodgson et al., 2005). It is one of the oldest beverages which is a completely non-alcoholic drink. Due to its therapeutic benefits, tea has become one of the most popular non-alcoholic beverages in the world. Its appeal as a "health drink" has increased significantly day by day.

Tea provides Bangladesh's entire domestic demand, which is of immense economic significance. Bangladesh is ranked 8th in terms of production (ITC, 2022). There are about 167 tea estates producing about 102.92 million kg of made tea in 2023 (BTB, 2023). Amongst our produced tea, a major percentage is only black tea (PDU, 2020). The tea sector in Bangladesh contributes 1% of the country's GDP, making it one of the main sources of revenue for the national treasury (Raza, 2019).

After manufacturing, tea is evaluated for quality and market value. This evaluation or assessment is commonly known as tea tasting. This is also called organoleptic taste. In the factory, the tea maker conducts tea tasting to maintain uniform products throughout the year and to prevent faults during manufacturing. Brokers of auction houses taste teas for valuation on behalf of the producers to obtain a fair price for the tea in the auction. Brokers also advise the producers on market demand. Tea buyer tastes the tea for it selling value, blending suitability and to maintain the standard of the blends (BTRI, 2009).

Due to the increasing cost of production and rising competition of newly emerging low-cost producer countries, it strongly needs to maintain the quality of tea. There is no alternative to organoleptic tea tasting method to judge the quality of tea at the factory or auction house. In our country, there is no uniform and standard tea tasting scoring or scaling method which can be followed by different tea estates, different factories, different broker houses or other organizations related to tea commerce. Besides, in recent times, Bangladesh Tea Board has fixed the base price of tea auction price in accordance with the quality of tea to deal with the unstable situation caused by the lower price of tea prevailing in the country (BTB, 2024). And that is why there is a need for standardization of quality assessment parameters of 'Organoleptic Tasting Method' that represents all teas of different qualities produced in our country as well as through which the quality of different teas can be determined in the same way. Therefore, evaluations of the produced tea from different tea estates are very essential through 'Organoleptic Tasting Method' along with a proper guideline of ideal quality parameters.

Materials and Methods

Tea samples from 65 tea estates from different regions of Bangladesh as well as samples from different 'Valley Tea Tasting Session' were collected. Teas were evaluated for developing standardizing the quality assessment parameters during organoleptic tasting method in respect of Bangladesh. For organoleptic tasting, at first, liquor was prepared by pouring boiling distilled water in a mug of a capacity of 142 ml in which 2.5 g tea was contained. After 05 minutes brewing, the lid covered mug the liquor was poured into a bowl and the infused leaf was shaken from the mug into the inverted lid, which was placed on top of the mug. Lastly tea was assessed through following technique (2.1) under three quality assessment parameters, such as: 'Dry Leaf Appearance', 'Infused Leaf Appearance' and 'Liquor Characteristics' described below (Appendix I):

Tea Tasting Technique:

- **Slurping:** Aerate the tea to fully appreciate the flavours.
- **Rolling the Tongue:** Distribute the tea across different taste buds to detect subtle notes.
- **Aftertaste:** Note the lingering flavours post-sip.

Dry Leaf Appearance:

Dry leaf appearances are very useful features in determining the general tea quality. This assessment is carried out, by observing the tea spread on a piece of white paper. During, assessment, following points are taken into consideration:

a) The uniformity of the grade- the size and form of the leaf, well made & clean, quite a good made, fair make & fairly clean.
b) Colour of the leaf- Black, blackish, blackish brown, brownish black, rather brownish, reddish etc.
c) Make and style of the leaf- Even, uniform, grainy & well curled.
d) Nose- Good nose, good bloom & shine.
e) Feel- Grity, brittle, bottom-line firing.

Infused Leaf Appearance:

Colour together with appearance and nose requires careful attention during the examination of the infused leaf. Apart from the desirable bright coppery colour the infused leaf may show the following variations: coppery bright, bright, fairly bright, fair greenish, dull mixed dullish (Greenish is often associated with the high nitrogen content of the leaf).

Liquor Characteristics

In order to taste the liquor, the taster takes some of the liquor into his mouth with a sucking noise. The liquor is swilled around the tongue and brought into contact with the palate and gums. In this way the taster assesses the thickness of the liquor by judging its viscosity, its bitterness by the taste on the back of the tongue, and its astringency and pungency by the sensation apprehended on parts of the cheek and the gums. All these factors together make up the briskness, strength, body & brightness of the liquor. Tea aroma and flavour are assessed by drawing the liquor to the back of the mouth up to the olfactory nerve in the noses. A mouthful of liquor is thus felt, tasted and smelled and after tasting spit out into a spittoon.

Results and Discussion

Tea samples from different tea estates were evaluated through organoleptic tasting method under the following parameters 'Dry Leaf Appearance', 'Infused Leaf Appearance' and 'Liquor Characteristics'. Different qualities of each parameter are described below**:**

Dry Leaf Appearance

Generally, 'Dry Leaf' is evaluated by rating alphabetically (A, B, C and D). From Table 1, it was observed that 'Extraordinary' quality leaf rated as 'A' and described as 'Attractive grades being black, well made and clean, grainy, uniform size, even, well curled, excellent bloom & shine and excellent nose. Commendable in all respect.' 'Excellent' quality leaf rated as 'A-' and described as 'Attractive grades being black, well made and clean, grainy, good size, even, good bloom and good nose. Commendable in all respect.' 'B+', 'B' and 'B-' quality teas were rated for 'Best', 'Good' and 'Fairly Good' teas respectively. Again, 'Fair', 'Average' and 'Below Average' types teas were rated as 'C+', 'C' and 'C-' respectively. Lastly, 'Poor' quality teas are rated as 'D' which described as 'Dull, reddish, poor make and poorly clean'.

Table 1. Different types of 'Dry leaf' and their category

Sl no	Description of different types of dry leaf	Dry Leaf Quality	Dry Leaf Rating
1	Attractive grades being black, well made and clean, grainy, uniform size, even, well curled, excellent bloom & shine and excellent nose. Commendable in all respect.	Extraordinary	**A**
2	Attractive grades being black, well made and clean, grainy, good size, even, excellent bloom and excellent nose. Commendable in all respect.	Excellent	**A-**
3	Attractive grades being black, well made and clean, grainy, good size, even, good bloom and good nose.	Best	**B+**
4	Blackish, quite a good made, fair size, even and quite clean, possessing a fair bloom.	Good	**B**
5	Blackish brown, fair make and fairly clean, good size and quite even	Fairly Good	**B-**
6	Brownish black or slightly brownish, of a fair make (not bad not good in between), but quite even with fair amount of fibre.	Fair	**C+**
7	Rather brownish, a little flaky, a little uneven with fibre, only fair make.	Average	**C**
8	Quite brown and flaky and uneven with fiber.	Below Average	**C-**
9	Dull, reddish, poor make and poorly clean.	Poor	**D**

Infused Leaf Appearance

Colour of together with appearance and nose requires careful attention during the examination of the infused leaf. Different categories of infused leaf based on colour were given in Table 2. When colour of the infused leaf was 'Coppery Bright', it was termed as 'Excellent'. On the other hand, 'Best' for 'Bright' color as well as 'Good' for both 'Quite Bright' and 'Fairly Bright'. Again, when the color was 'Fair' and 'Only Fair', the infused leaf was categorized as 'Average' and 'Below Average' respectively. The term 'Dull mixed/ Dullish/ Dull' was used for 'Poor' colored infused leaf.

Table 2. Different category of 'Infused Leaf' based on colour

Sl No	Category	Infused leaf Colour
1	Excellent	Coppery Bright
2	Best	Bright
3	Good	Quite Bright
4		Fairly Bright
5	Average	Fair
6	Below Average	Only fair
7	Dull mixed/ Dullish/ Dull	Poor

Liquor Characteristics

During tasting of liquor, different liquor characteristics were assessed for individual sample: liquor colour, strength, briskness, brightness, flavour, any manufacturing faults etc. In Table 3, liquor of different quality with their ratings and descriptions were given. In case of liquor assessment, ratings were given in a numeric scale i.e. from 1 to 5. Rating of 5 was given for 'Extraordinary' tea which was described as – 'Exceptionally good teas having very good colour, useful strength, briskness, brightness, body, fullness, and also a lot of character (flavour). Commendable in all respect.' 'Excellent' quality was related with liquor of 'Very good colour, useful strength, briskness, brightness, body, fullness and character (flavour)'. Ratings of 3 excellent types teas differ with 'Character of Flavour', such as: '4+' for 'good character', '4' for 'fair character' and '4-' for 'little character'. Liquor with 'Good colour, good strength, good body' was denoted with 'Good' quality tea. There were four types of 'Good' quality teas, defer from different 'Body' of the liquor. The term 'Body' is refers to 'Liquor having both fullness and strength as opposed to being thin'. The liquor rating of '3+ pref' was for 'good body', '3+' was for 'fair body', '3' was for 'some body' and '3-' was for 'little body'. On the other hand, both liquor of '2+' and '2' were for 'Medium/ Average' quality, were described as 'Fair colour and some strength' and 'Some colour with only a little strength' respectively. When liquor was 'Plain and thin, only a little colour', was termed as 'Below Average' with the rating of '2-'. Liquor of 'Poor/ Faulty/ Unacceptable' quality was termed as 'Poor' with the rating of '1'.

Table 3. Different types of 'Infused leaf and their description

Sl no	Description of different types of liquor	Liquor Quality	Liquor Rating
1	Exceptionally good teas having very good colour, useful strength, briskness, brightness, body, fullness, and also a lot of character (flavour). Commendable in all respect	Extraordinary	**5**
2	Very good colour, useful strength, briskness, brightness, body, fullness and good character (flavour)	Excellent	**4+**
3	Very good colour, useful strength, briskness, brightness, body, fullness and some character (flavour)		**4**
4	Very good colour, useful strength, briskness, brightness, body, fullness and little character (flavour)		**4-**
5	Good colour, good strength, good body	Good	**3+ pref (preference)**
6	Good colour, good strength, fair body		**3+**
7	Good colour, good strength, some body		**3**
8	Good colour, good strength, little body		**3-**
9	Fair colour and some strength	Medium/ Average	**2+**
10	Some colour with only a little strength		**2**
11	Plain and thin, only a little colour	Below Average	**2-**
12	Poor/ Faulty/ Unacceptable tea	Poor	**1**

Conclusion

Organoleptic tea tasting can provide a comprehensive and direct measurement of the perceived intensity of target attributes, such as appearance, color, aroma, taste and texture. The purpose of tea tasting is to describe and evaluate teas in the form of individual grade or as blended product. These include the appearance of the dry leaf, of the infused leaf and characteristics of the liquor obtained by brewing the tea with boiling water. Tea tasting is performed by factory men for quality assessment, by brokers for a valuation price, by buyers to making choice or to buy tea and by blenders to maintain the standard of the blends. Tea samples from different sources were evaluated for standardizing the quality assessment parameters during organoleptic tasting method in respect of Bangladesh. Dry Leaf' was evaluated by rating alphabetically (A, B, C and D) with different quality such as Extraordinary, Excellent, Best, Good, Fairly Good, Fair, Average, Below Average and Poor based on appearances of dry leaf. 'Infused leaf' was classified by different colours such as coppery bright, bright, quite bright, fairly bright, fair, only fair and poor. Finally, 'Liquor' was categorized with Extraordinary, Excellent, Good, Medium/ Average, Below Average and Poor category with ratings of 5, 4+, 4, 4-, 3+ pref, 3+, 3, 3-, 2+, 2, 2- and 1 rating by assessing colour, strength, briskness, brightness, flavour, any manufacturing faults etc. of liquor.

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Appendix I: Pictorial representation of sample colletion and tea tasing of different samples.

Fig. 1. Tea Tasting session at North Sylhet Valley Club

Fig. 2. Ready Batches for Tasting samples

Fig. 3. Tasting of different samples at BTRI Tea Tasting room

Fig. 4. Different samples of different tea grades

Fig. 5. Ideal quality tea with infused leaf

Fig. 6. Liqour of particular grade

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DEVELOPMENT OF SUSTAINABLE MANUFACTURING PROTOCOL OF 'GOLDEN TIPS TEA' WITH DIFFERENT CLONAL COMBINATIONS IN RESPECT OF BANGLADESH

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Abstract

The cheapest beverage after water is tea which is also becoming more and more well-known as a significant "health drink" due to its possible therapeutic benefits. The present experiment was carried out to develop a standardized manufacturing protocol for 'Golden Tips Tea' by using different clonal combinations in respect of Bangladesh. The whole experiment was conducted in the following two steps. In first step, five treatments with four replications based on oxidation time (T_1 = 60 minutes, T_2 = 70 minutes, T_3 = 80 minutes, T_4 = 90 minutes, and T_5 = 100 minutes) were used to standardize the protocol. After standardizing the manufacturing protocol, second step was conducted to develop quality-full Golden Tips Tea by using buds of three different clonal varieties with their nine combinations (C_1 =100% BT2, C_2= 50% BT2 + 50% BT4, C_3= 80% BT2 + 20% BT4, C_4= 100% BT4, C_5= 50% BT4 + 50% BT23, C_6= 80% BT4 + 20% BT23, C_7= 100% BT23, C_8 = 50% BT2 + 50% BT23, C_9= 80% BT2 + 20% BT23) in respect of Bangladesh. The manufacturing protocol of T_4 treatment (65% withering + ideal rolling + oxidation for 90 minutes + drying at 180-200^{0}F for 30 minutes) with the varietal combination of 80% BT2 + 20% BT4 (C_3) gave the best result for producing Golden Tips Tea. Better quality Golden Tips Tea can also be produced by the combination of C_1 (100% BT2) and C_9 (80% BT2 + 20% BT23). But, in the case of producing bulk amount of Golden Tips Tea, using only BT23 (C_7 combination) could be more cost-effective which was 'Above Average' quality type. During whole experiment, room temperature was maintained 86 ^{0}F (30 ^{0}C) and relative humidity at 94% was strictly followed.

Keywords: Golden Tips Tea, Quality, Manufacturing Protocol, Clonal Combination

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Introduction

Since ancient times, drinking tea has been associated with health benefits (Khan and Mukhtar, 2013). With its possible therapeutic potential, it has been increasingly gaining acceptance as a significant "health drink" (Hicks, 2009). Due to its abundance of healthy amino acids, vitamins and antioxidants, tea's prominence has gradually increased over the past few decades (Lin et al., 2019). Tea has a variety of secondary metabolites that are directly linked to its quality, including free amino acids, polyphenols and alkaloids, which are all extremely aromatic, flavorful and beneficial to health (Too et al., 2015).

Due to specific requirements of climate and soil, tea cultivation is confined only to certain specific regions of the world. Since 1854, when the first tea garden 'Malnicherra Tea Estate' in Sylhet was established, tea has been grown commercially in Bangladesh (Arefin and Hossain, 2022). Being one of the main agro-based sectors, tea is a significant cash crop in Bangladesh. In 2023, about 168 tea estates produced 102.92 million kg of made tea. (BTB, 2023).

The increasing demand for tea along with this rapidly growing population of Bangladesh has created a huge domestic market for the tea industry in Bangladesh. In addition to increasing the production of tea, there is a need to improve the quality of tea and add diversification. Although tea production in recent years was as expected, tea auction prices were not so much satisfactory level. To survive in the export market, besides reducing the cost of production, the production quality of tea should be increased as well and tea diversification should be introduced.

Different types of teas are manufactured in other countries based on people's tastes, habits, and culture. Tea may generally be divided into three categories according to how it is processed: fully oxidized tea- (i) CTC black tea, (ii) Orthodox black tea, (iii) Golden Tips Tea, partially oxidized tea (i) Oolong tea (ii) Yellow tea and fully non-oxidized tea (i) Green tea, (ii) White tea (Arefin et al, 2020). 'Golden Tips Tea' is a kind of oxidized tea that differs from its golden colour appearance and excellent flavour i.e., Taste & Aroma. Since "Golden Tips Tea" requires an extensive amount of labor and years of actual skill, it might be considered an instance of "Artisan Tea" The Golden Tips Tea is created from the young buds of select tea bushes, and cultivating them requires a keen understanding of both the tea plant and the environment in which they grow. The plucking process is an art in itself, where only the very best leaves are handpicked to ensure the highest quality. The buds are subject to prolonged oxidation, allowing them to retain their golden colour and exquisite taste.

In Bangladesh, there is not enough literature or production manufacturing knowledge about Golden Tips Tea thus planters are still more or less ignorant about Golden Tips Tea processing. This paper will give a concrete idea about the standardized manufacturing protocol of Golden Tips Tea using different clonal combinations of Bangladesh.

Material and methods

Two experiments were carried out subsequently at BTRI Miniature Factory from March 2023 to December 2023 to develop a sustainable manufacturing protocol for Golden Tips Tea in Bangladesh. The whole experiment was conducted in the following two steps.

1. Standardizing the protocol: The manufacturing protocol of the Golden Tips Tea was standardized in this step. Based on oxidation time five treatments with four replications were used in this step. Fresh buds of the BT2 cultivar were initially harvested, and rigorous adherence to 65% withering and optimum rolling was maintained throughout the production process. After oxidation of different treatments, immediately drying at 180-200 ^{0}F for 30 minutes was repeated to bring down the moisture to 3%. During this experiment, room temperature was maintained 86 ^{0}F (30 ^{0}C) and relative humidity at 94% was strictly followed. To obtain good quality golden tips tea, the only unopened bud was plucked and processed. Unopened hairy buds are commonly desired for the best quality of golden tips tea. Treatments of this step are given below:

Treatments		Manufacturing protocol
T_1	=	Withering + Rolling + Oxidation for 60 minutes + Drying
T_2	=	Withering + Rolling + Oxidation for 70 minutes + Drying
T_3	=	Withering + Rolling + Oxidation for 80 minutes + Drying
T_4	=	Withering + Rolling + Oxidation for 90 minutes + Drying
T_5	=	Withering + Rolling + Oxidation for 100 minutes + Drying

2. Effect of different clonal combination: After standardizing the manufacturing protocol, this step was conducted to develop quality-full Golden Tips Tea by using different clones with their different combinations in respect of Bangladesh. Three BTRI-released clonal varieties, such as BT2, BT4 and BT23 along with nine combinations having each of four replications were used in this step, as follows:

Treatments		Manufacturing protocol
C_1	=	Golden Tips Tea from only BT2.
C_2	=	Golden Tips Tea from 50% BT2 + 50% BT4.
C_3	=	Golden Tips Tea from 80% BT2 + 20% BT4.
C_4	=	Golden Tips Tea from only BT4.
C_5	=	Golden Tips Tea from 50% BT4 + 50% BT23.
C_6	=	Golden Tips Tea from 80% BT4 + 20% BT23.
C_7	=	Golden Tips Tea from only BT23.
C_8	=	Golden Tips Tea from 50% BT2 + 50% BT23
C_9	=	Golden Tips Tea from 80% BT2 + 20% BT23

Here, the variety BT2 has a consistent touch of flavour as like as Orchids while BT4 is a quality clone (having the characteristics of malty taste) and BT23 has silver needle long tips (Hossain et al, 2018; BTRI, 2021).

Traditional organoleptic tea tasting method was used to evaluate the quality of each Golden Tips Tea treatments. During quality test, dry leaf appearance, infused leaf appearance and liquor characteristics were assessed and scored numerically out of 50 marks, as mentioned below:

Table 1. Parameters of conventional organoleptic tasting of Golden Tips Tea

Parameters	Points
1. Dry Leaf Appearance	10 points
2. Infused Leaf Appearance	10 points
3. Liquor characteristics (30 points):	
3.1. Liquor colour	10 points
3.2. Flavour	10 points
3.3. Brightness	10 points
Total =	**50 points**

Quality scores were recorded and analyzed statistically using 'Statistix 10' for every parameter. For categorize Golden Tips Tea, we developed a "Quality Category" based on organoleptic tasting scoring (out of 50 points) which is as below:

Table 2. Quality category of golden tips tea

Quality category	Score
E = Excellent	≥ 34 out of 50
AA = Above Average	34 > to ≥ 32 out of 50
A = Average	32 > to ≥ 30 out of 50
BA = Below Average	<32 out of 50

Results and Discussion

1. ***Standardizing the protocol***

Based on five oxidation times (60, 70, 80, 90 and 100 minutes), the manufacturing protocol of the Golden Tips Tea was standardized. The main characteristics of Golden Tips Tea are 'Golden Tippy' like dry leaf appearance, infused leaf of 'Coppery bright' color with high flavour and 'Golden Bright' brightness.

From Table 3, it was found that, a 'Golden Tippy' like dry leaf appearance was found in T_4 treatment (7.51) which was followed by T_2 treatment (6.93) and T_3 treatment (6.89). The inferior quality was observed in T_5 treatment (6.79) which was 'Dark Tippy' as well as T_1 treatment (6.81) due to prolonged oxidation. In the case of infused leaf appearance, 'Coppery bright' color infused leaf was observed in T_4 treatment (6.42) which was followed by both T_3 treatment (6.24) and T_5 treatment (6.23) were statistically similar. 'Very good color' liquor was found in T_4 treatment (7.45) which was followed by both T_1 treatment (7.19) and T_5 treatment (7.21) were statistically similar. Interestingly, in case of flavour, 'High' flavour (6.15) was observed both T_4 and T_5 treatment while 'Medium' flavour was found in rest of the treatments. Again, Brightness of 'Golden Bright' color was found in T_4 treatment (7.41) while inferior brightness was observed in both T_1 treatment (7.14) and T_5 treatment (7.15) were statistically similar.

Based on the total points and quality category from Table 3, it was revealed that the 'Excellent' quality (34.94) type Golden Tips Tea was obtained by maintaining the manufacturing protocol of T_4 treatment (65% withering + ideal rolling + oxidation for 90 minutes + drying at 180-200 ^{0}F for 30 minutes) followed by T_3 treatment (33.67), T_5 treatment (33.53), T_2 treatment (33.52) and T_1 treatment (32.97) gave 'Above Average' Quality Category.

So, from this experiment it can be concluded that, superior quality Golden Tips Tea can be obtained by 65% withering + ideal rolling + oxidation for 90 minutes + drying at 180-200 ^{0}F for 30 minutes where room temperature at 86 ^{0}F (30 ^{0}C) and relative humidity at 94% will be strictly maintained.

Table 3. Liquor characteristics with scoring of Golden Tips Tea of different treatments.

Treatments	Dry Leaf Appearance (10 Points)	Infused Leaf Appearance (10 Points)	Liquor Colour (10 Points)	Flavour (10 Points)	Brightness (10 Points)	Total Points (50)	Quality Category**
T_1 (60 min)	6.81 d (Tippy)	5.74 c (Fairly Bright)	7.19 b (fair color)	6.09 ab (Medium)	7.14 b (Bright)	32.97	AA
T_2 (70 min)	6.93 ab (Silvery Tippy)	5.98 bc (Quite Bright)	7.29 ab (good color)	6.11 ab (Medium)	7.21 ab (Fairly Bright)	33.52	AA
T_3 (80 min)	6.89 bc (Tippy)	6.24 b (Bright)	7.31 ab (good color)	6.04 b (Medium)	7.19 ab (Fairly Bright)	33.67	AA
T_4 (90 min)	7.51 a (Golden Tippy)	6.42 a (Coppery bright)	7.45 a (Very good color)	6.15 a (High)	7.41 a (Golden Bright)	34.94	E
T_5 (100 min)	6.79 d (Dark Tippy)	6.23 b (Bright)	7.21 b (fair color)	6.15 a (High)	7.15 b (Bright)	33.53	AA
LSD at 5% level of Significance*	0.04	0.17	0.12	0.05	0.08	-	-

* *Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)*
** *E = Excellent, AA = Above Average, A = Average and BA = Below Average*

2. *Effect of different clonal combination*

Three BTRI-released clonal varieties, such as BT2, BT4, and BT23 along with their nine combinations were used in this step to study the different clonal effects on produced golden tips tea. Some parameters of fresh bud of different clonal varieties were studied which was provide in Table 4. It was observed that long fresh bud (4.61 cm) and higher 1000 fresh bud weight (65.27 g) was found in BT23 while smaller bud size (2.93 cm) and lower 1000 fresh bud weight (51.75 g) were found in BT4 clonal variety. The number of pubescence was observed more in BT4 (1825) while lower in BT23 (1628).

Table 4. Some parameters of fresh bud of different clonal varieties

Clonal varieties	Fresh Bud size (cm)	1000 Fresh Bud Weight (g)	Number of Pubescence
BT2	3.56 b	56.68 b	1684 b
BT4	2.93 c	51.75 c	1825 a
BT23	4.61 a	65.27 a	1628 c
LSD at 5% level of Significance*	0.59	4.84	54.47

* *Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)*

Fresh buds of nine combinations of three clonal varieties were collected and Golden Tips Tea was produced through standardized protocol (65% withering + ideal rolling + oxidation for 90 minutes + drying at 180-200^{0}F for 30 minutes) stated above. From Table 5, it was observed that, dry leaf appearances of all combinations were 'Golden Tippy' type, but best 'Golden Tippy' appearance was observed in C_1 combination (7.45). There was no significant deference in infused leaf appearance because standardized protocol was followed. 'Very good liquor color' was found in C_3 combination (7.47) with C_1 combination (7.43). 'High' flavour due to 80% BT2 flavour as like as Orchids and 20% BT4 (deserves the characteristics of Malty tastes with golden bright liquor colour) was noticed in C_1 combination (6.17). C_3 combination (6.17) with C_9 combination (6.08) also gave high flavour. 'Golden Bright' type brightness was observed in both C_1 combination (7.42) and C_3 combination (7.41) while rest of the combinations were 'Fairly Bright'.

So, it was revealed that, clonal combination of C_3 (80% BT2 + 20% BT4), C_1 (only BT2) and C_9 (80% BT2 + 20% BT23) produced 'Excellent' quality golden tips tea. The highest quality score was performed by C_3 (34.91) along with C_1 (34.88) and C_9 (34.36) which were statistically similar. Plucking of leaf buds is very laborious and smaller-sized buds require more labour thus more expensive than prolonged-sized buds. The bud size and 1000 fresh bud weight of clonal variety BT23 are much more than the other clonal varieties, thus plucking of buds only from BT23 would be more cost-effective than the other combinations due to less plucking cost of labour. So, if any planter wants to produce bulk amount of golden tips tea, he can produce golden tips tea from only BT23 (C_7 combination) which could be 'Above Average' quality type (33.85).

Table 5. Liquor characteristics with scoring of Golden Tips Tea of different treatments.

Clonal combination	Dry Leaf Appearance (10 Points)	Infused Leaf Appearance (10 Points)	Liquor Colour (10 Points)	Flavour (10 Points)	Brightness (10 Points)	Total Points 50	Quality Category**
C_1 (100% BT2)	7.45 a	6.41 (Coppery bright)	7.43 ab (Very good color)	6.17 a (High)	7.42 a (Golden Bright)	34.88	E
C_2 (50% BT2 + 50% BT4)	7.22 cd	6.37 (Coppery bright)	7.32 cd (good color)	5.83 ab (Medium)	7.23 bc (Fairly Bright)	33.97	AA
C_3 (80% BT2 + 20% BT4)	7.42 ab	6.44 (Coppery bright)	7.47 a (Very good color)	6.19 a (High)	7.41 ab (Golden Bright)	34.93	E
C_4 (100% BT4)	7.37 bc	6.29 (Coppery bright)	7.33 cd (good color)	5.59 de (Medium)	7.25 bc (Fairly Bright)	33.93	AA
C_5 (50% BT4 + 50% BT23)	7.21 d (Golden Tippy)	6.39 (Coppery bright)	7.34 bc (good color)	5.61 cd (Medium)	7.24 bc (Fairly Bright)	33.79	AA
C_6 (80% BT4 + 20% BT23)	7.23 cd (Golden Tippy)	6.41 (Coppery bright)	7.35 bc (good color)	5.63 cd (Medium)	7.21 c (Fairly Bright)	33.83	AA
C_7 (100% BT23)	7.36 bc (Golden Tippy)	6.38 (Coppery bright)	7.31 d (good color)	5.55 e (Medium)	7.25 bc (Fairly Bright)	33.85	AA
C_8 (50% BT2 + 50% BT23)	7.22 cd (Golden Tippy)	6.32 (Coppery bright)	7.32 cd (good color)	5.83 bc (Medium)	7.24 bc (Fairly Bright)	33.93	AA
C_9 (80% BT2 + 20% BT23)	7.24 cd (Golden Tippy)	6.43 (Coppery bright)	7.35 bc (good color)	6.08 ab (High)	7.26 bc (Fairly Bright)	34.36	E
LSD at 5% level of Significance*	0.05	ns	0.02	0.09	0.03	-	-

** Within column values followed by different letter (s) are significantly different by DMRT (p≤ 0.05)*
*** E = Excellent, AA = Above Average, A = Average and BA = Below Average*

Fig. 1. Silver needle buds of different clonal varieties

Fig. 2. Dry Leaf of 'Golden Tips Tea'

Fig. 3. Infusion of 'Golden Tips Tea'

Conclusion

The Golden Tips Tea is a very royal-class quality tea that looks just as premium as it tastes. Tea planters in Bangladesh can increase their profit margin by producing this tea. For producing Golden Tips Tea, the manufacturing protocol of T_4 treatment (65% withering + ideal rolling + oxidation for 90 minutes + drying at 180-200^{0}F for 30 minutes) with the varietal combination of 80% BT2 + 20% BT4 (C_3) would be the best. Better quality Golden Tips Tea can also be produced by the combination of C_1 (100% BT2) and C_9 (80% BT2 + 20% BT23). But, in the case of producing a bulk amount of Golden Tips Tea, using only BT23 (C_7 combination) could be more cost-effective reducing plucking cost which was 'Above Average' quality type.

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EFFECT OF GRAFTING TECHNIQUE TO PRODUCE COMPOSITE TEA PLANT IN THE NURSERY FOR HIGHER YIELD AND DROUGHT RESISTANCE CAPACITY

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Abstract

Tea is one of the most popular beverages globally and Bangladesh surged to a record high of 102.92 million kg in the just-concluded year of 2023. Environmental factors play a major role in tea growing and tea plants are vulnerable to water deficiency stress. Grafting is one of the techniques that have been developed to help crops become more resilient to drought stress. The current study was aimed to develop drought resistant tea plants as well as to increase the yield by grafting technique using different rootstock and scion combinations. Hence, the current experiment with three phases was conducted in Bangladesh Tea Research Institute (BTRI) VP nursey and BTRI main field from 2019 to 2023 consisting four treatments i.e. T_1 = (BTS1 rootstock+ BT2 scion), T_2 = (BTS1 rootstock+ BT12 scion), T_3 = (BTS1 rootstock+ BT15 scion) and T_4 = (BTS1 rootstock+BT17 scion) with control BT2. Sprouting percentage and the success of grafting after four months were same but Shoot Extension Rate (SER) of T_1 treatment showed significantly higher than the other treatments. Plant height, shoot-root dry weight and total dry matter was observed the higher in T_1 treatment and BT2, which were statistically similar; but the lower rooting depth was found in control BT2 because rooting system of BT2 was fibrous root while rest of the treatments had tap root system. The depth of root was found highest in T_1 treatment which can be helpful to mitigate drought stress than the other treatments. At third phase of the experiment, all the yield contributing characters, such as plant height, number of branches, Tea Pruning Litter (TPL) and green leaf yield were found higher in T_1 treatment and control BT2 which were statistically similar. Therefore, it can be concluded that, the use of T_1 treatment (BTS1 rootstock+ BT2 scion) will be a best solution to mitigate the drought problem along with more production in drought prone areas of Bangladesh.

Keywords: Tea, Grafting, Yield, Drought, Composite Tea Plant

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Introduction

One of the most significant drinks in the world is made from tea [*Camellia sinensis* (L.) O. Kuntze] which is a woody perennial crop (Maritim et al., 2015). There are a total of 168 tea estates and tea production of Bangladesh surged to a record high of 102.92 million kg in the just-concluded year of 2023 (BTB, 2024). Due to insufficient rainfall early in the season, tea plantations had lesser productivity; nevertheless, from that point on, favorable weather and supporting actions resulted in the bumper harvest.

However, various environmental factors play major role in tea growing but tea plants are specially vulnerable to water deficiency stress. Climate change might lead to less predictable growth conditions in near future, the places where the crop is now grown. In most tea-growing regions, the length and intensity of droughts as well as the frequency of frosts have risen, which has led to lower tea production (Tanton,1982) and arise in pest activity (Kamunya et al., 2008). In addition to raising plant mortality to about 19%, drought can result in a 33% loss in a tea crop (Cheruiyot et al., 2009). Many studies have been conducted to develop technology that would guarantee continuous tea production even during times of drought stress in order to reduce difficulty.

A plant's root system is essential because it controls numerous aspects of the growth and development of the shoots. Because it is essential to both the entire growth of the crop and its progress, the root system is known as the "hidden half" (Eshel and Beeckman, 2013). It has long been believed that plants' root systems serve a vital function because they not only provide nutrients but also generate and transport physiological catalysts (Mohd-Radzman et al., 2013).

Tea plants can be propagated sexually (from seed grown) or through cloning (from stem cutting) (Zhang et al., 2021). Compared to the tap roots of seedling plants, the root system of clonal plants is often shallow because of their fibrous roots (Yamasiilta, 1994). However, tea is mostly propagated by "cuttings," which consist of an internode and a leaf from the aperiodic shoots of pruned bushes, because of their higher production potential and quick multiplication. In the tea industry, stenting, or the grafting of fresh cuttings, is a particular approach for creating high-quality composite plants by fusing the rootstock's drought resistance with the scion's production and quality (Sharma, 2011). The practice of grafting tea plants was first introduced in Japan in 1902. After then, it was explored exclusively in the USSR, Indonesia, and Formosa, and it was thought to be very challenging to make the procedure effective. Tea plant grafting has now become simpler because of the advancements in technique of plastic bag, watering, and shading procedures. As a result, it is determined that grafting tea plants has significant practical applications in reducing the time needed to breed a new variety, propagating it quickly through multiplication and replanting and/or reestablishing a low-yielding tea garden. Its feasibility is greatly anticipated in Japan, India, and other nations (Sanai et al., 1962 and Grice, 1968).

Grafting is one of the strategies that has been discovered to help crops to become more resilient to drought (Razi and Muneer., 2023). By regulating the physiological and molecular processes of the plants, this strategy has been found to be a reliable and efficient way to increase the plants' adaptability to drought (Yang et al., 2022). In light of the aforementioned, the current study set out to assess a number of unique graft combinations utilizing prospective scions and rootstocks in an effort to widening the choice of graft combinations that are compatible. In addition, a number of morphological and yield-related variables were evaluated in the grafted plants in order to determine if higher production and drought tolerance of the composite plants were comparable with those of the self-rooted clonal plants.

Materials and Methods

The current experiment was conducted in Bangladesh Tea Research Institute (BTRI) VP nursery and BTRI main field from 2019 to 2023. Bi-clonal seeds of BTRI released BTS1 variety were sown in December 2019 to get seedlings which were used as 'root stocks' for cleft grafting.

TRI released four clonal tea plants e.g. BT2, BT12, BT15 and BT17 of same age were selected for 'scion'. So, the treatments were as T_1 = (BTS1 rootstock+ BT2 scion), T_2 = (BTS1 rootstock+ BT12 scion), T_3 = (BTS1 rootstock+ BT15 scion) and T_4 = (BTS1 rootstock+ BT17 scion). The 'cleft grafting' for the treatments was done very precisely and grafted plants were kept in completely covered with transparent polythene for favorable condition and highest success rate.

The whole experiment was conducted in three phases. In first phase, Sprouting%, Success% and Shoot Extension Rate (SER) were observed after four months of grafting. Grafted tea plants were maintained in the nursery for about a year until they were ready for transplantation into the main field. In the main field, plants of four treatments (T_1, T_2, T_3 and T_4) were planted along with non-grafted BT2 plants of same age which were used as control. In second phase, data were collected on plant height (cm), rooting depth (cm), dry weight of root-shoot (g) and total dry matter of the grafted plants during the time of planting in the main field. After collection of data of second phase, 'decentering pruning operation' was done at 6-9 inches for every plants of the experimental field. During decentering, data on plant height (cm), number of branches and weight of pruning liters(kg) were collected. Green leaf yield (g/plant) of each treatment were collected after plants reached to tipping height.

The Duncan's Multiple Range Test (DMRT) was used to compare means after the analysis of variance was calculated by Statistix 10 software. The Bar Graph was prepared by using Microsoft Office Excel version 2019.

Results and Discussions

a) Observations of the First Phase (Sprouting%, Success% and Shoot extension rate)

Sprouting%, Success% and Shoot extension rate (SER) were observed after four months of grafting. In several crops, the cleft grafting led to a significantly higher final sprouting success and seedling development (Saleem et al., 2013). The key requirement for the effective grafting process and the sustained viability of grafted plants is the taxonomic compatibility of the scion and root stock. Scion vigor and its water interactions are mostly influenced by rootstock (Rasool et al., 2020). Form the table 1, it was observed that sprouting percentage and the success of grafting after four months were not significantly different for treatments. The uniform sprouting and success percentage of the treatments can be described as the favorable combination of root stock and scion as well as the use of same root stock (BTS1) amongst the treatments.

Table 1. Effect of treatments on Sprouting%, Success% and Shoot extension rate after four months

Treatments	Sprouting percentage	Success percentage	Shoot extension rate (SER)
T_1 = (BTS1 rootstock+ BT2 scion)	90.80 a	87.60 a	9.2 a
T_2 = (BTS1 rootstock+ BT12 scion)	96.40 a	87.20 a	5.0 b
T_3 = (BTS1 rootstock+ BT15 scion)	87.60 a	80.80 a	5.4 b
T_4 = (BTS1 rootstock+ BT17 scion)	94.40 a	89.60 a	5.8 b
CV (%)	18	20	7.5
LSD (p=0.05)	21.84	23.96	3.48

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

Growth is considered to be the most drought-sensitive physiological process in plants. The process of meristematic cell division generates daughter cells, which in turn stimulate the young cells to expand and eventually lead to shoot development. But under extreme lack of moisture the xylem's ability to provide water to the elongating cells is reduced, which prevents the cells from elongating (Maritim et al., 2015). Similar to many other plants, development of tea shoots is mostly regulated by both genetic and variables from the external environment. Typically, the Shoot Extension Rate (SER) is used to calculate the frequency of shoot growth (De Costa et al., 2007). The SER of T_1 treatment (9.20mm) showed significantly higher than the other treatments (Table1). The variation within the SER of the treatments can be explained due to the variation of the scion used in the experiment. Wickramaratne's (1981) findings further suggested that the variance in shoot extension rates between clones might be caused by inherited differences in shoot internode and leaf size characteristics.

b) Observations of the Second Phase (plant morphological characters)

Data of plant height, rooting depth, dry weight of root-shoot and total dry matter of the grafted plants during the time of planting in the main field were collected in second phase and shown in Table 2. The highest plant height (60.1 cm) was observed in BT2 (control) which was statistically similar with T_1 treatment (59.87 cm). The highest rooting depth (14.25 cm) was found in T_1 treatment while lowest in control BT2 (12.15 c) because rooting system of BT2 was fibrous root while rest of the treatments had tap root system. Shoot dry weight was found higher in both T_1 treatment and BT2 which were statistically similar. The highest root dry weight was found in both T_1, T_3 and BT2 which were statistically similar while lowest in T_2 treatment. The generation of total dry matter and the accumulation of nutrients in crops are usually strongly associated with crop yield (Rhoads and Stanley., 1981). Total dry matter (14.31) was observed highest in T_1 treatment and BT2 which were statistically similar while the lowest performance was observed in T_2 treatment.

Table 2. Effect of treatments on Plant height, rooting depth, shoot dry weight, root dry weight and total dry matter in second phase

Treatments	Plant height (cm)	Rooting depth (cm)	Shoot dry weight (g)	Root dry weight (g)	Total dry matter
T_1 = (BTS1 rootstock+ BT2 scion)	59.87 a	14.25 a	10.84 a	3.47 a	14.31 a
T_2 = (BTS1 rootstock+ BT12 scion)	43.37 c	11.75 b	9.11 b	2.43 b	11.54 c
T_3 = (BTS1 rootstock+ BT15 scion)	56.50 b	13.25 ab	9.89 ab	3.18 a	13.07 b
T_4 = (BTS1 rootstock+ BT17 scion)	56.75 b	12.25 ab	10.06 ab	2.93 ab	12.99 bc
BT2	60.1 a	12.15 c	10.83 a	3.46 a	14.29 a
CV (%)	10.94	12.01	8.67	13.03	9.34
LSD (p=0.05)	2.96	2.39	0.09	0.63	0.67

Within column values followed by different letter (s) are significantly different by DMRT ($p \leq 0.05$)

c) Observations of the Third Phase (yield contributing characters)

At third phase data on plant height, number of branches during decentering, weight of pruning liters (kg) during decentering and green leaf yield (g/plant) were collected. All data are graphically presented in Fig. 1-4.

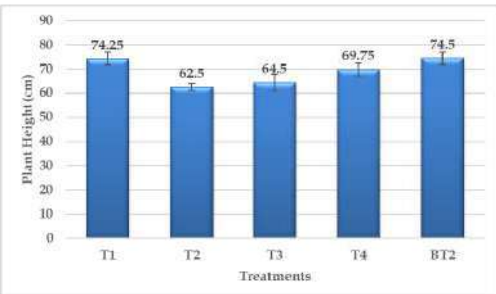

Fig. 1. Plant height (cm) during decentering

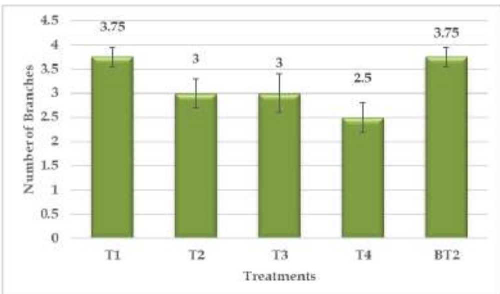

Fig. 2. Number of branches during decentering

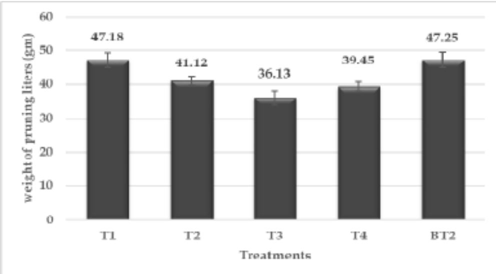

Fig. 3. Weight of pruning liters (kg) during decentering

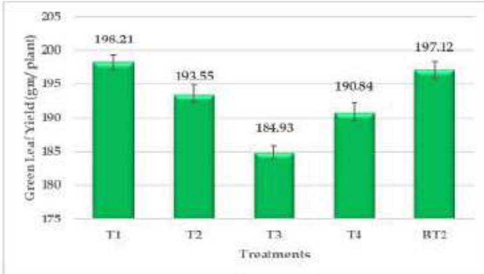

Fig. 4. Green leaf yield (g/plant)

There is a strong positive correlation with plant height and crop yield in different crop species, such as: wheat (Gao et al., 2020), faba bean (Ji et al., 2022), sorghum (Pereira and Lee, 1995), barley (Scheurer et al., 2001), cassava (Okogbenin and Fregene., 2003), maize (Pereira and Lee, 1995) etc. From Fig 1, it was observed that, the highest plant height was observed in BT2 and T_1 treatment which were statistically similar and the lowest height was found in T_2 treatment. In case of number of branches, the highest number of branches (3.75) were seen in T_1 treatment and BT2, where the rest were lower. Different studies have found a high correlation between the yield per plant and the number of branches, such as: rice (Gong et al., 2022), Soybean (Xu et al., 2021), black cumin (Gashaw et al., 2020) etc. When the tea plant is pruned, Tea Pruning Litter (TPL) is produced which is preserved on the outermost layer of the soil (Borgohain et al., 2023). In this experiment, highest pruning liters (47.25 g)were found during the decentering of plants of BT2 which was statistically similar with T_1 treatment (47.18 g). The highest green leaf per plant was observed in T_1 treatment (198.21 g)and BT2 (197.12 g) which were statistically similar while lowest yield was observed in T_3 treatment (184.93 g). Increased photosynthetic capacity, carbon assimilation rate and antioxidant enzyme capacity are probably the causes of grafting-mediated drought resistance (Javid et al., 2011). Roots can significantly contribute to improving drought as well as other stress adaptation and higher productivity. In this experiment, all the treatments were grafted mediated where same BTS1 root stocks were used with different scions. But in case of yield, plants of BTS1 rootstock+ BT2 scion as well as control BT2 gave statistically similar highest results. Therefore, the development of plants depends significantly on their root systems, which in turn control the growth and development of their shoots (Kaysar et al., 2022, Wang et al., 2014, Wang and Frei, 2011).

Conclusion

The results of present study demonstrate the impact of many variables on the improved efficiency of grafted plants. Additionally, it is suggested that nursery grafting may provide a way to mitigate clones' vulnerability to drought. Differences in the yield of a scion with same rootstocks clearly show the significance of stock–scion compatibility. This experiment was conducted in three phases to find out the best stock–scion compatibility along with higher productivity. Sprouting percentage and the success of grafting after four months were same but Shoot Extension Rate (SER) of T_1 treatment showed significantly higher than the other treatments. Plant height, shoot-root dry weight and total dry matter were observed higher in T_1 treatment and BT2 which were statistically similar but lower rooting depth was found in control BT2 because rooting system of BT2 was fibrous root while rest of the treatments had tap root system. The depth of root was found highest in T_1 treatment which can be a way to mitigate drought condition more than the other treatments. At third phase of the experiment, all the yield contributing characters, such as plant height, number of branches, Tea Pruning Litter (TPL) and green leaf yield were found higher in T_1 treatment and control BT2 which were statistically similar. So on the basis of above three experiments it can be concluded that, the use of T_1 treatment (BTS1 rootstock+ BT2 scion) will be a best solution to mitigate the drought problem along with more production in drought prone areas of Bangladesh.

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APPROACHES OF COMBINED WEED CONTROL SYSTEM IN MATURE TEA PLANTATIONS

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Abstract

An experiment was conducted at the Bangladesh Tea Research Institute Farm & Bilashcherra Experimental Farm during 2019–2020 to determine the best weed management combinations for managing weeds in matured tea plantations. Five treatments were used in the experiment, each of which was duplicated three times using RCBD. Every two weeks, data on the percentage of weed reduction and the weekly harvesting of green leaves were gathered. Every treatment exhibited a somewhat notable fluctuation in the yield of made tea and the percentage of weed growth compared to the control. The treatment (T_3), Chilling + Indaziflam (pre-emergent herbicide) + Paraquat (post-emergent herbicide) showed maximum reduction of weed density (67%) over the control followed by (T_5) simultaneous application of Indaziflam + Paraquat + Sickling, where the weed reduction percentage is 63.46%. Therefore, higher mean yield (1837 kg/ha) was obtained from T_3 which is following by T_5, Where the mean yield is 1785 kg/ha over the control. Among the treatments used, Chilling + Indaziflam + Paraquat produced the best gross margin return and was also shown to be the most cost-effective. It is advised that the most cost-effective and efficient combinations for managing weeds in established tea farms are Chilling + Indaziflam + Paraquat, taking into account all the parameters.

Keywords: Mature Tea, Weeds, Integration, Reduction, Yield, Cost-effective.

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Introduction

Globally, tea is considered as the second largest & cheapest popular beverage after water. Its area of cultivation & production percentages is significantly increasing day bay day not only in Bangladesh but also in the whole world, where weed act as one of the major limiting factor on its expansion. They only become troublesome when the farm is expected to suffer substantial economic losses. These troublesome weeds cause significant financial losses in developing as well as industrialized countries despite advancements in technology. (Auld, 2004). Weeds are commonly strong plants and that's why their demands for mineral nutrients are usually excessive. In tea, the weeds can consume up to 252 kg of soil nutrients per hectare per year. (Chakravartee and Barbora, 1995). In addition to competing with the tea plants for basic needs, they also provide a habitat for a variety of diseases and pests. For sustainable productivity, tea plants require optimum agronomic maintenance like other plantation crops. However, weeds are the ones who absorb and release huge quantities of water, and this loss is amplified during dry spells. Weeds hinder tea because they compete with it for nutrients, moisture, light, and space. Thus, it leads to the reduction of plant growth and yield of tea.

Uncontrolled weed growth in tea plantations can result in a 10–50% reduction in yield. (Rajkhowa et. al., 2005; Deka & Barua, 2015). Because of weed infestation the global tea industry's yearly crop loss has been assessed to be 146 million kg. It is about to 14-15% crop losss of the total crop production (Rana et. al., 2020). Globally, weeds damage crops to an even greater extent than other pests.

Normally in mature tea plantations, factors like large ground exposure, heavy rainfall, use of nitrogenous fertilizer trigger the profuse weed growth. Ground exposure during land clearing & after pruning phases initiates enormous growth of weed in tea plantations. Under the humid conditions, the weed grows rapidly during the period of rainfall, when tea is heavily flushed. The majority of tea garden laborers frequently engage on plucking and other essential intercultural activities during this period, that's why it is quite difficult to control weed by manually. Normally in the tea gardens of Bangladesh, Weeding has been executed chemically (with herbicides) or manually (sickling, cheeling, and hoeing). However, maintaining weed-free conditions in these areas with hand tools or a single herbicide application isn't always feasible. Man days and a certain amount of round spray are needed regularly. Additionally, the price of weeding accounts for roughly 10% to 14% of all the overall cost of field operations. Additionally, it accounts for 4-5% of the entire cost of producing made tea, coming in second only to fertilizer application and plucking. (Prematilake, 2003). The rising cost of herbicides and the high cost of labor make weeding more and more expensive every day. For sustainable production of tea, methods for effectively and inexpensively controlling weeds in established plantations are crucial.

On the other hand, weeds may become habituated to and tolerant of such methods if only a few or one methods is applied to manage them over an extended period of time. (Bhowmic, 1997). The use of alternative weed management techniques, such integrated weed management (IWM), is becoming more and more popular these days. (Pannell, 1990; Swanton and Weise 1991; Clements, Weise and Swanton, 1994; Auld, 2004). Integrated Weed Management (IWM) employs a variety of different long-term weed management tactics, including mechanical removal, biological agents, genetic characteristics, cultural approaches, and chemical weed control. For the remaining approaches to remain suitable for usage in the future whenever the reliance on one technique is reduced. (Swanton and Weise, 1991). Therefore, a variety of management techniques are employed in IWM to prevent weeds from developing the ability to adjust to a continually shifting environment. The experiment was conducted to determine the most effective and sustainable combination of weed management strategies for managing weeds in matured tea plantations.

Materials and Methods

The experiment was carried out at Bangladesh Tea Research Institute & Bilascherra Experimental Farm during 2019-20 in mature tea plot with varied stand weeds. The experiment was carried out with five treatments and three replications using randomized complete block design. The plot size was 4.0 × 4.0 m². T_1= Control, T_2= Chilling (Mechanical control) + Pendimithalin (pre-emergent herbicide) + Paraquat (post-emergent herbicide), T_3= Chilling (Mechanical control) + Indaziflam (pre-emergent herbicide) + Paraquat (post-emergent herbicide), T_4= Simultaneous application of Pendimithalin + Paraquat + Sickling, T_5= Simultaneous application of Indaziflam + Paraquat + Sickling. Using a knapsack spayer, herbicide treatments were given after the weeds had completely covered the ground and before they began to flower. Visual rating on a 100-point scale (0 being no control and 100 representing complete control) was used to evaluate the efficacy. . The mean data were expressed in percentages. Yield data was collected in terms of weekly weight of green leaves. Using the Statistix-10 application, all gathered data have been collated and statistically examined.

Results and Discussion

Table 1 demonstrates that T_3 outperforms the control in terms of weed reduction percentage (67%) and is followed by T5 (63.46%). T_2 and T_4, which had weed reduction percentages for the trial period of 34.23% and 29.60% over the control, come after T_5. It can be noted that using Indaziflam and then Paraquat (T_3) after the chilling operation gives the highest percentage of weed reduction and the longest period of weed-free state. It may be very useful in areas that have been pruned to LP and DSK. Simultaneous application of Indaziflam, Paraquat and after then sickling (T_5) give the second most weed reduction percentage which may be applied in other skiffed areas of tea plantation.

Similar outcomes were attained by Kappro and Hall (2011) using Indaziflam in forestry and turf. According to Sharma's (1980) research, pre-emergence efficacy of herbicides climbed linearly with dosage and provided effective control for a full 12-week period. Perry with his scientists (2011) showed that one application of Indaziflam may be able to manage certain summer and winter weeds. for 29 weeks after treatment. Sebastian et al. (2017) also reported on the long-term control of certain invasive annual grasses and the elimination of these invasive grasses' soil seed bank with the application of Indaziflam.

The results of various treatment combinations indicate that T_3 produced the highest mean yield (1837 kg/ha), followed by T_5, whose mean yield is 1785 kg/ha (Table 2). The yield from treatments T_4 (1716 kg/ha) and T_2 (1691 kg/ha) came after the yield from treatment T_5. T_1, where frequent practice was conducted, produced the lowest yield (1605 kg/ha). This result showed that T_3 had the highest yield, which was 14.45% higher than the control.

Table 1. Weed growth as percentage over various treatment combinations

Treatments	Weed growth%	Reduction of weed growth% over the control
Control	54.16 c	00
Chilling (Mechanical control) + Pendimithalin (pre-emergent herbicide) + Paraquat (post-emergent herbicide)	35.62 b	34.23%
Chilling (Mechanical control) + Indaziflam (pre-emergent herbicide) + Paraquat (post-emergent herbicide)	18.00 a	67%
Simultaneous application of Pendimithalin + Paraquat + Sickling	38.125 b	29.60%
Simultaneous application of Indaziflam + Paraquat + Sickling.	19.79 a	63.46%

According to DMRT, values inside columns denoted by distinct letter(s) differ significantly ($p \leq 0.05$).

Table 2. Yield gained from different treatment combination.

Treatments	Mean yield of green leaf (kg/ plot)	Mean yield of green leaf (kg/ ha)	Mean yield of made tea (kg/ ha)
T_1	11.16 c	6,980 c	1,605 c
T_2	11.76 b	7,350 b	1,691 b
T_3	12.78 a	7,988 a	1,837 a
T_4	11.94 b	7,463 b	1,716 b
T_5	12.42 a	7,763 a	1,785 a
LSD at 5% level	0.56		
CV	1.75		

According to DMRT, values inside columns denoted by distinct letter(s) differ significantly ($p \leq 0.05$).

Table 3. Partial budget analysis of integrated weed management practices on the yield of tea.

Treatment	Yield of made tea (kg/ha)	Variable cost (Tk/ha)			Gross return (Tk/ha)	Gross margin (Tk/ha)
		Herbicide	Labour	Total		
T_1	1605	2940	2040	4980	321000	316020
T_2	1691	2980	12,155	15,135	338200	323065
T_3	1837	3230	12,155	15,385	367400	352015
T_4	1716	2980	5270	8250	343200	334950
T_5	1785	3230	5270	8500	357000	348500

Supposing, price of Indaziflame group herbicide= 15000 Tk/litre, Pendimithaline= 1000 Tk/litre, Paraquat= 350 tk/litre, price of made tea =200 Tk/kg, Labour wage= 170 Tk/day.

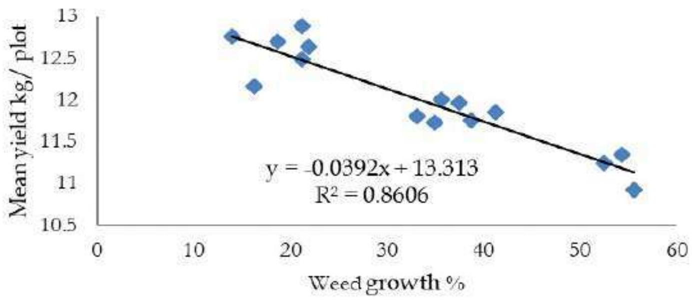

Fig. 1. Correlation between weed growth% and mean yield kg/plot.

Weed growth percentage and mean yield kg/plot parameter have a very strong negative relationship, as shown in Fig. 1. The yield parameter moves upward in response to a decrease in the percentage of weed growth and downward in response to an increase in the percentage of weed growth.

Conclusion

Considering yield of made tea and economic analysis viewpoint it can be concluded that, the application of Indaziflam and Paraquat following a chilling operation provides the highest percentage of weed reduction and the longest duration of weed-free conditions. To achieve better results, more research may be done combining novel herbicide molecules with other IWM components. Tea industry will be benefited by enhancement of crop yield by sustainable management of tea weeds for longer period of time in a cropping season.

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RESPONSE OF BIO-SLURRY BASED COMPOST ON SOIL PROPERTIES AND YIELD OF MATURE TEA

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Abstract

A field experiment was conducted at the Bangladesh Tea Research Institute (BTRI) farm from January 2022 to December 2022 to evaluate the effect of bio-slurry based compost applications on the yield of mature tea (*Camellia sinensis* L.). At the same time, the use of inorganic fertilizers was minimized with the gradual increase of doses of bio-slurry based compost. Compost and chemical fertilizers were administered in varying amounts in six distinct treatments, each with three replications. The plucking data was recorded every seven days during the harvest season. The highest yield (1968 kg/ha) of made tea was recorded in the treatment T_6, where 6 t/ha bio-slurry based compost with 40% of the recommended dose of chemical fertilizer was applied. The rate of increase over control was 19.64%. In contrast, the treatment T_4 (3 tons/ha bio-slurry based compost + 70% of the recommended dose of chemical fertilizer) was found more effective considering the economic viewpoint. The maximum usage of bio-slurry based compost and the reduced rate of chemical fertilisers from the recommnded dosages enhanced tea production, and the increase in yield due to varied treatments was statistically significant ($^{ANOVA}F$ = 3.51, p < 0.05). Besides the highest yield, the treatment T_6 plot showed a maximum increase in organic carbon (1.24 ± 0.07 %), total nitrogen (0.128 ± 0.01 %), available phosphorus (104.76 ± 3.72 mg/kg) and calcium (303.03 ± 4.08 mg/kg).

Keywords: Bio-slurry, compost, chemical fertilizer, yield, tea

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Introduction

As a perennial crop, growing tea requires a prolonged period of monoculture cultivation (Phukan et al., 2019). Managing nutrient levels in the tea field is crucial, and chemical fertilizers are the primary source of nutrient supply for tea plants. The dependency on chemical fertilizers has decreased the amount of organic matter and beneficial microbes in the tea garden soils, reducing the soil's tilth and fertility (Zohora et al., 2022). In addition to harming the environment, heavy and frequent applications of mineral fertilizers deteriorate soil properties. Alternative approaches are being sought after due to the excessive expense of chemical fertilizers, the widening gap between supply and demand, and their detrimental effects on the environment. However, it is generally acknowledged that the secret to increasing crop productivity is to apply fertilizer in a balanced manner while effectively using other inputs (Gebrewold and Yildiz, 2018).

An alternative strategy for effectively and economically regulating soil fertility to achieve sustainable crop production is the integrated nutrient management system (Han et al., 2016). As an alternative, the integrated nutrient management system uses less inorganic fertilizer and combines it with organic resources, including composts, crop residues, animal manures, and green manure (Chen, 2008). Using organic and inorganic fertilisers in tandem plays a vital role in maintaining soil fertility. In particular, the combination of organic and inorganic fertilizers leads to a more significant increase in microbial biomass and improves soil health (Elkholy et al., 2010). It lowers the cost of suggested inorganic fertilizer and increases its effectiveness of usage (Abedi et al., 2010). The optimal combination of mineral and organic fertilizers depends on the ecological circumstances and land use system.

The use of different types of compost as a source of organic fertilizers is being very popular nowadays. Bio-slurry is an organic substance produced as a byproduct of biogas facilities via anaerobic digestion of methane gas. It can be used in liquid, compost, and dry form and is a very good fertilizer/composting substance for crops (Warnars and Oppenoorth, 2014). On the other hand, bio-slurry from biogas digesters has an average plant nutrient content of about 0.75% nitrogen, 0.65% phosphorus and 1.05% potassium (Demont et al., 1991). According to Abubaker et al. (2015), bio-slurry prevents ammonia oxidation and denitrification, improving plant performance by reducing soil nitrogen losses. However, very few experimental investigations have explored the effects of bio-slurry based compost applications on the yield of tea and changes in tea garden soil properties. This study sought to ascertain the optimal dosage of bio-slurry-based compost and how it affected tea productivity, which can be used to ensure cost-effective use of chemical fertilizers in sustainable tea production.

Materials and Methods

An experiment was carried out at BTRI Farm (24° 17' 36.8″ N and 91° 44' 49.5″ E) to evaluate the impact of bio-slurry based compost on the characteristics of the soil and the production of mature tea. The experiment was laid out in a Randomized Block Design, having 6 treatments with three replications. The unit plot size was 4.2 m × 2.5 m. Nitrogen (N), Phosphorus (P) and Potassium (K) nutrients were applied through urea, triple super phosphate (TSP) and muriate of potash (MOP), respectively, based on the average yield of the experimental site. Before fertilization, dolomite was applied in every experimental plot except for the control, which depended on soil pH and sufficient soil moisture. Chemical fertilizers were applied after a good shower of rain of 15-20 cm. Urea and MOP fertilizer were applied in two splits and TSP fertilizer was applied during the 1st split application in the cropping season. The first dose of fertilizer was applied in April, and the second dose in the first week of August 2022. Bio-slurry-based compost was applied and mixed with the soil by light forking in two splits 15 days before chemical fertilizer application. During the tea-harvesting season, the weight of the green leaves was recorded every seven days to determine the yield. Intercultural activities, including pruning, irrigation, and pest control were carried out as and when required.

Treatment details

T_1 = Control (No organic manure and chemical fertilizer)
T_2 = 100% RCFD* (N^{100}, P^{30}, K^{60} kg/ha)
T_3 = 1.5 tons/ha Bio-slurry based compost + 85% RCFD
T_4 = 3.0 tons/ha Bio-slurry based compost + 70% RCFD
T_5 = 4.5 tons/ha Bio-slurry based compost + 55% RCFD
T_6 = 6.0 tons/ha Bio-slurry based compost + 40% RCFD

**RCFD= Recommended Chemical Fertilizer Dose*

Soil sample collection and analysis method

In order to measure various soil physio-chemical parameters, such as soil texture, pH, organic carbon (%), total nitrogen (%), available phosphorus (mg/kg), potassium (mg/kg), calcium (mg/kg), and magnesium (mg/kg), initial and post-harvest soil samples were taken from a depth of 0-23 cm by using the soil sampling tools called 'Auger'. Soil texture was determined by the hydrometer method. A pH metre (WTW InoLab pH 7110) was used to determine the pH of the soil samples. The soil suspension was made using distilled water at a ratio of 1:2.5 soil to water (Huq and Alam, 2005). Walkley and Black's wet oxidation method (1934) was used to quantify the amount of organic carbon in the soil. For the determination of total nitrogen Micro Kjeldahl steam distillation method was applied (Huq and Alam, 2005). Colorimetric estimation of available phosphorus was done using the ascorbic acid method (Murphy and Riley, 1962). Available potassium, calcium and magnesium were extracted with 77% ammonium acetate solution (Peterson, 2002). Available K was determined by flame photometer (BUCK-Scientific PEP7), while calcium and magnesium were determined by atomic absorption spectrophotometer (Analytik Jena novAA 400P).

Compost analysis method

Physical and chemical analysis of the applied bio-slurry based compost was done before field application. The moisture % was calculated as a percentage for the compost using a moisture analyzer (KERN DBS60-3). The organic carbon (%) of the compost was determined by using Muffle Furnace (JISICO. Model: J-FM-28) at 550°C as reported by Yeomans and Bremner (1988). The pH of the compost was determined in compost–water suspension (1:10) according to Jodice *et al.* (1982) by using a pH meter (WTW InoLab pH 7110). Total nitrogen (N) was ascertained by utilizing the Micro Kjeldahl steam distillation technique (Huq and Alam, 2005). Total P was determined by the colorimetric method (Blue color method) using a spectrophotometer (JENWAY 6300) (Peterson, 2002). For determination total potassium (K), total calcium (Ca), total magnesium (Mg), total zinc (Zn) and total Copper (Cu) of the compost sample were digested by the nitric acid-perchloric acid digestion method and determined using the Atomic Absorption Spectrophotometer (AAS) (Analytik Jena novAA 400P) as described by Huq and Alam, 2005.

Data Analysis

Statistical analyses, such as descriptive statistics, one-way analysis of variance (ANOVA) and DMRT (Duncan's multiple range test) were performed using the statistical software SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Partial budget analysis, such as gross return and net return for every treatment applied to the yield of tea was calculated.

Results and Discussion

Physico-chemical analysis of bio-slurry based compost applied in the experimental plots reveals that, most of the nutrient content and other properties were within the critical limits set by the Bangladesh government (Table 1).

Tea may be produced on a variety of geologically derived soils. In Bangladesh quaternary and recent alluvial soils are prevalent. Low fertility, high acidity, and heavy weathering characterise tea garden soils. In addition, flooding does not deposit fertile silt on these soils; rather, it suffers from erosion (Saha et al., 2022). The soil analytical results showed that the study area had a pH, organic carbon (O.C), total nitrogen (N), available phosphorus (Av. P), available calcium (Av. Ca), and available magnesium (Av. Mg) within the critical limit and available potassium (Av. K) below the critical limit of tea soil (Table 2).

Table 1. Physico-chemical properties of bio-slurry based compost.

Parameter	Analytical result	Government Approved Critical Limits (Ahmmed *et al.*, 2018)
Color	Dark Gray	Dark Grey to Black
Odor	Absence of foul odor	Absence of foul odor
Physical Condition	Non granular	Non granular
Moisture%	18.46	10 - 20
pH	7.2	6.0 - 8.5
Organic Carbon %	10.13	10 - 25
Total Nitrogen %	1.72	0.5 - 4.0
C:N	8:1	20:1(max)
Total Phosphorous %	2.65	0.5 - 3.0
Total Potassium %	0.53	0.5 - 3.0
Total Calcium %	2.11	-
Total Magnesium %	0.24	-
Total Zinc %	0.03	0.1 (max)

The pH values of the treatment plot were significantly ($p<0.05$) affected by the treatments compared to control (Table 3). It was observed that the pH values of soil decreased in the treated areas over control, and the lowest value was found in T_4 and T_6 where 3 tons/ha and 6 tons/ha bio-slurry based compost were applied with 70% and 40% of the recommended dose of chemical fertilizer. The decrease in pH in almost every treatment might be due to the release of organic acids from the compost (Ding et al., 2020).

Table 2. Initial soil fertility in the experimental field.

Location	Texture	pH	O.C (%)	Total N (%)	Av. P (mg/kg)	Av. K (mg/kg)	Av. Ca (mg/kg)	Av. Mg (mg/kg)
BTRI Farm	SCl	5.8	1.06	0.12	71.74	43.89	202.09	39.92
Critical value	SL – L	4.5-5.5	1.0	0.1	10	80	90	25

The soil's organic carbon content increased relative to its initial value throughout each treatment except for treatment T_1 and T_2. The addition of chemical fertilizer did not cause the soil's organic carbon content to rise above its initial point; nevertheless, the treatments showed a more significant accumulation of organic carbon where bio-slurry based compost was applied. The plots treated with treatment T_6 had the highest increase in organic carbon (1.24 ± 0.07%) followed by T_5 and T_3 treated plots. The direct absorption of organic matter through organic manure in the soil may be the cause of the enhanced organic carbon content of the soil in the plots receiving the combined application of inorganic fertilisers and bio-slurry based compost (Saha et al., 2022). In addition, the close proximity of all the plots to one another may have had an impact on the organic carbon content of the plots.

Table 3. The results of soil analysis at the completion of the experiment.

Treatment	**Texture**	**pH**	**O.C** (%)	**Total N** (%)	**Av. P** (mg/kg)	**Av. K** (mg/kg)	**Av. Ca** (mg/kg)	**Av. Mg** (mg/kg)
T_1	SCl	5.8 ± 0.06 ^{a}	1.06 ± 0.04 ^{c}	0.127 ± 0.02 ^{b}	72.97 ± 6.69 ^{c}	40.07 ± 4.21 ^{b}	207.90 ± 4.24 ^{c}	40.87 ± 1.41 ^{d}
T_2	SCl	5.7 ± 0.07 ^{ab}	1.03 ± 0.03 ^{c}	0.108 ± 0.01 ^{a}	83.94 ± 4.32 ^{bc}	53.06 ± 8.50 ^{ab}	211.73 ± 7.37 ^{c}	45.79 ± 1.57 ^{d}
T_3	SCl	5.5 ± 0.13 ^{abc}	1.15 ± 0.04 ^{abc}	0.119 ± 0.01 ^{a}	87.16 ± 6.88 ^{b}	42.07 ± 7.22 ^{b}	288.30 ± 8.29 ^{ab}	94.21 ± 2.11 ^{a}
T_4	SCl	5.3 ± 0.12 ^{c}	1.09 ± 0.04 ^{bc}	0.111 ± 0.01 ^{a}	87.33 ± 6.70 ^{b}	43.90 ± 5.47 ^{b}	275.57 ± 3.55 ^{b}	71.75 ± 1.82 ^{b}
T_5	SCl	5.5 ± 0.09 ^{bc}	1.22 ± 0.04 ^{ab}	0.119 ± 0.03 ^{a}	94.25 ± 3.69 ^{ab}	69.35 ± 5.98 ^{a}	295.47 ± 8.36 ^{ab}	60.76 ± 3.07 ^{c}
T_6	SCl	5.3 ± 0.06 ^{c}	1.24 ± 0.07 ^{a}	0.128 ± 0.01 ^{a}	104.76 ± 3.72 ^{a}	65.01 ± 5.15 ^{a}	303.03 ± 4.08 ^{a}	75.06 ± 2.87 ^{b}

Note: Mean ± standard error within each row followed by a different letter indicates significant differences at $p<0.05$ according to Duncan's multiple range test (DMRT).

The plot treated with 6.0 tons/ha Bio-slurry based compost with 40% recommended chemical fertilizer showed a maximum increase in total nitrogen (0.128 ± 0.01%). The build-up of organic matter brought on by applying organic manure may be the reason for the rise in the total N content in the soil under the treatments. Additionally, organic matter decreased nitrogen losses, increasing the amount of total nitrogen in the system. Several studies revealed that the total N and organic C content of the soil, as well as the amount of accessible nutrients, are all significantly increased when inorganic and organic fertilizers are used together, improving the overall characteristics of the soil (Ali et al., 2009; Zhao et al., 2014 Mahmood et al., 2017; Redda and Kebede, 2017).

The available phosphorus content of the soil over its initial concentration was increased in every treatment, including control. The addition of phosphatic fertilizers might cause an increasing trend of phosphorus concentration in experimental plots. Plots treated with 6 tons/ha bio-slurry based compost with 40% of the recommended dose of chemical fertilizer showed the highest increase in available phosphorus (104.76 ± 3.72 mg/kg) relative to its initial value. Research has demonstrated that additions of organic manure can influence the adsorption and desorption of P in soil and directly raise the P pool in soils (Johan et al., 2021).

The content of available potassium (mg/kg) in soil was found to significantly ($p<0.05$) vary among the treatments, and the maximum potassium (69.35 ± 5.98 mg/kg) content was found in treatment T_5 treated plots where 4.5 tons/ha Bio-slurry based compost and 55% of recommended doses of chemical fertilizers were applied together. The results also revealed that there were no significant differences between the treatments T_5 and T_6.

On top of that, the concentrations of available calcium (Ca) and available magnesium (Mg) were also significantly ($p<0.05$) varied among the treatments over the control. The concentrations of calcium in every plot were increased over the control. The concentrations of Ca in different treatments decreased in order: $T_6>T_5>T_3>T_4>T_2>T_1$. Meanwhile, the highest concentration of Mg was recorded in the plots receiving treatment T_3. The annual dolomite application may cause the soil's rising Ca and Mg contents (Saha et al., 2022).

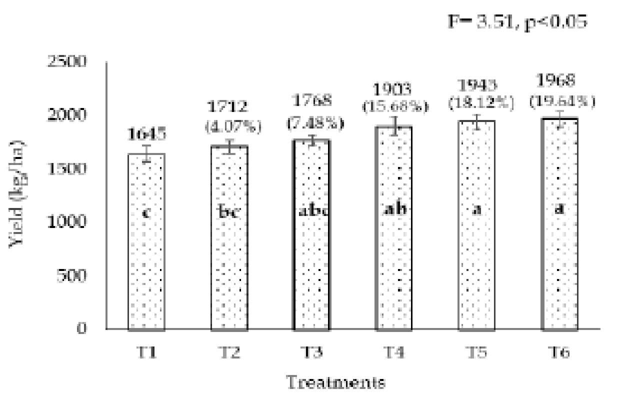

Fig. 1. Bar chart showing the effect of different treatments on the yield of tea. Figures in the parentheses above each bar represent the rate of increase over control. The different letters within each bar indicates significant differences at $p<0.05$ according to Duncan's multiple range test (DMRT).

The impact of different treatments on the mean yield of tea is illustrated in Fig. 1. The outcome shows that the mean yield over control rose with each treatment. Yields obtained from different treatments reveal that a comparatively higher mean yield of 1968 kg/ha was obtained from the treatment T_6 (4.5 tons/ha Bio-slurry based compost + 55% RCFD) that was closely followed by the yield of 1943 kg/ha from the treatment T_5 (3.0 tons/ha Bio-slurry based compost + 70% RCFD). The lowest yield of 1645 kg/ha was obtained from the treatment T_1 where no fertilization was done. However, from the result, it was observed that the highest yield increase was found in treatment T_6 (19.64 %) followed by treatment T_5 (18.12%) over control and the lowest yield increase over control was found in treatment T_2 (4.07%). The yield increase from various treatments was statistically significant ($p<0.05$).

In the present study, it has been observed that there was no significant difference between T_5 and T_6, which means applying bio-slurry based compost @ 4.5t/ha with 55% recommended fertilizer dose was as effective as bio-slurry based compost @ 6t/ha with 40% recommended chemical fertilizer dose. However, there were significant differences between the treatments mentioned in T_1 and T_2. There was also significant variation between treatment T_4 and T_1. Saha et al. (2022) reported that a ligher tea yield was obtained by combining organic and inorganic fertilizers. It was reported that applying bio-slurry increased 11% yield of tea, whereas, in the present study, the yield increased to 19.64% (SNV, 2011). Several earlier studies support the following conclusions: The application of bio-slurry increases the growth and yield characteristics of field crops and delivers both macronutrients (N, P, K) and micronutrients (Zn, Mn, B) (Islam et al., 2010; Kumar et al., 2015; Ferdous et al., 2020; Roeswitawati et al., 2021).

Table 4. Partial budget analysis of the treatments applied to the yield of tea.

Treatment	Yield of Made Tea	Variable Cost Fertilizer	Variable Cost Labour	Variable Cost Total	Gross Return	Net Return
	(kg/ha)	(Tk/ha)				(Tk/ha)
T_1	1645	0	0	0	296100	296100
T_2	1712	10304	850	11154	308160	297006
T_3	1768	20756	3400	24156	318240	294084
T_4	1903	31195	5780	36975	342540	305565
T_5	1943	41647	8160	49807	349740	299933
T_6	1968	52141	10540	62681	354240	291559

Note: Gross return = yield × price of a particular product; net return = gross return - variable cost. Assuming, the price of bio-slurry based compost = 8 Tk/kg, Urea = 22 Tk/kg, TSP = 20 Tk/kg and MOP = 13 Tk/kg, made tea = 180 Tk/kg, labour wage = 170 Tk/day.

The partial budget analysis of the treatments applied on the yield of tea (Table 5) indicated that the highest net return was found in the treatment T_4 (305565 Tk/ha), which was followed by the treatment T_5 (299933 Tk/ha), T2 (297006 Tk/ha), T_1 (296100 Tk/ha) and the lowest net return was found in the treatment T_6 (291559 Tk/ha). Therefore, compared to the treatment T_1, almost all applied treatments were economically viable except T_3 and T_6. Although the highest yield of tea was found in the treatment T_6, the highest net return was obtained from treatment T_4. Hence, the dose 3 tons/ha bio-slurry based compost with 70% RCFD is more effective considering the economic viewpoint.

Conclusion

The management of tea plantations heavily depends on the supply of nutrients, which is mostly achieved by chemical fertilisers. However, it is widely accepted that a balanced fertiliser application along with efficient use of other inputs is the key to raising crop output. By using 3 tons/ha bio-slurry based compost in tea plantation can reduce 30% use of chemical fertilizers and thus ensure agricultural sustainability and further reduce environmental pollution. The findings revealed that applying bio-slurry based compost and chemical fertilizers combinedly has some significant advantages in the production of tea and improvement of tea soil quality.

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