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**Research Article**

# Influence of shade and organic nutrition on growth, yield and quality of memory enhancing herb, *Brahmi* (*Bacopa monnieri* L.)

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**ABSTRACT**

Memory enhancing herb - *Brahmi* (*Bacopa monnieri* L.) has growing national and international demand owing to its various medicinal properties. In order to study the influence of shade and nutrient levels, an experiment was laid out in strip plot design with shade levels as the main plots (35% shade, 50% shade and 100% sunlight) and nutrients requirement as sub plots [50, 75 and 100% N equivalent through FYM, 50, 75 and 100% N equivalent through vermicompost, RDF (100:60:60 kg NPK/ha), RDF (100:60:60 kg NPK/ha) + FYM (10 t/ha)]. The results revealed that among different shade levels tried, superior plant growth, fresh and dry herbage yield and cumulative dry herbage yield of seven harvests were obtained in 35% shaded condition compared to 50% shade and open conditions. Among different nutrient levels tried, conjunctive use of recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha) gave the highest dry herbage yield (16.35 t/ha), which was *on par* with organic treatment consisting of 100% N equivalent through FYM + Arka microbial consortium @ 12.5 kg/ha/year (16 t/ha). However, highest content of bacopasaponin C and bacoside A were observed in 100% sunlight condition (1.88 and 2.93%, respectively) and in integrated nutrient management treatment. The results were very promising for acceptance of *Brahmi* for commercial cultivation especially in organic production scenario to ensure steady supply of quality raw material to cater the increasing national and international demand.

**Keywords:** *Brahmi*, shade requirement, INM, organic farming, herb yield, bacoside A

## INTRODUCTION

*Bacopa monnieri* L. (Family: Scrophulariaceae), commonly known as '*Brahmi*', '*Neera-Brahmi*' or '*Jalanimba*' is a creeping and succulent herb, generally growing in damp and marshy places throughout India to an altitude of 1320 m. In *Ayurveda* it is categorized as *'Medhya rasayana',* meaning memory enhancer. Besides, its renowned status as memory vitalizer, it is used to treat respiratory, cardiac and neuro pharmacological disorders like depression, psychosis, insanity, insomnia, epilepsy and stress (Rajani, 2008). Medicinal property of this plant is attributed mainly to saponins called bacosides. Bacoside A and B are the key active constituents of this medicinal herb. *Brahmi* market can be segmented into food and beverage industry, personal care industry and pharmaceutical industry based on its end use. *Brahmi* is used as nutritional drink ingredient and as herb in food and beverage industries. As tablets and tonics, it is used in health supplement products, while, its oil and paste are used in hair care products. The powder can be used by consumers directly or for preparation of different products to increase their nutritional value. In the pharmaceutical industries, it is used as brain health wellness supplement. For personal care also it is used as hair care

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and skin care products. Various commercial formulations like '*Brahmirasayanam', 'Brahmighritam*', 'Mentat' and 'Memory plus' etc. are some of the popular *Ayurvedic* drugs prepared from this plant. Use of bacoside as brain tonic for enhancing memory has amplified the international demand for this herb and it has been exploited for many years from its natural habitat (Rahman *et al.,* 2002).

*B. monnieri* is classified as one among the botanicals in high trade in Herbal *Mandis* with a trade of 200-500 MT/ year and the estimated annual consumption of *Brahmi* is 140.62 MT /year (Goraya and Ved, 2017). However, this plant is mainly collected from marshy waste lands, paddy fields, farm bunds, garden lands and moist forest lands, and is rarely cultivated. In general, *Brahmi* is a shade loving crop and in its natural habitat, it is found growing under shaded conditions. Due to unsustainable harvesting methods wherein the whole plants including roots are harvested, their population is dwindling at a rapid rate and poor recovery of the active principles from these raw materials has also been observed. The biggest market for the *Brahmi* products in terms of consumer is in Asia Pacific region. Globally, China and India are the largest exporters of *Brahmi* products. The increase in demand for the natural products in Northern American and European markets has an immense potential for the *Brahmi* products to flourish. Hence, from these regions high demands for *Brahmi* products are anticipated (https:// www. Transparency market research. com/ brahmi-market.html). However, very limited efforts have been made for its commercial cultivation, development of agronomic practices and post-harvest management, especially under South Indian conditions. Besides, strict regulation rules regarding quality can hinder the *Brahmi* products to enter specific market regions, the hold down that most of the *ayurvedic* and nutraceutical products face. Therefore, there is an urgent need to develop greener cultivation practices for this medicinal herb to reduce the existing stress on natural population and to ensure steady delivery of raw material to pharmaceutical industry. Hence, this present investigation was undertaken to standardize shade and nutrient requirements of *Brahmi* for sustaining higher productivity and quality.


**Figure 1: Effect of different shade levels and nutrients on growth and yield of *Brahmi* during first harvest** (A. 35% shade ($S_1$); B. 50% shade ($S_2$); C. 100% sunlight ($S_3$); D. INM treatment RDF (100:60:60 kg NPK/ha) + FYM (10 t/ha) - $N_8$)

## MATERIALS AND METHODS

### Experimental site

The study was done at the ICAR - Indian Institute of Horticultural Research (IIHR), Bengaluru, Karnataka, India during 2017-2019 (Figure 1). It is situated in south-east tract of Karnataka state at 12°58' North latitude and 77°34' East longitude and at an altitude of 900 m above mean sea level. The study site comes under semi-arid, sub-tropical climate with hot summer and cold winter with an average rainfall of 866 mm. The largest part of the rainfall is received from the south-west monsoon during July to August (Figure 2). Bulk soil sample was collected from the study site before initiating the experiment for analyzing initial soil physicochemical parameters. The experimental soil is Fluventic Ustochrept and detailed physicochemical parameters were analyzed as per the standard procedures (Table 1).

### Experimental design and treatment details

The experiment was laid out in strip-plot design with different shade levels as the main factor A ($S_1$–35% shade, $S_2$-50% shade and $S_3$-100% sunlight) and nutrient requirement as Factor B [$N_1$:50% N equivalent through FYM, $N_2$:75% N equivalent through FYM, $N_3$:100% N equivalent through FYM, $N_4$:50% N equivalent through vermicompost, $N_5$:75% N equivalent through vermicompost, $N_6$:100% N equivalent through vermicompost, $N_7$: recommended dose of fertilizers (100:60:60 kg NPK/ha), $N_8$:recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha)] in three replications.

### Field experiment

The experiment was conducted for a period of two years, i.e. from June, 2017 to June, 2019. Physical and chemical properties of initial experimental soil were analyzed and presented in Table 1. The land was thoroughly prepared by repeated ploughing and beds of 4.0 m × 1.0 m were prepared. For different shade experiments, 35% and 50% shade nets were erected using aluminium pipes as support. Shade percentage was estimated using Line quantum sensor meter and expressed in photosynthetically active radiation (PAR). The PAR recorded was 380 µm/s/m$^2$, 550 µm/s/m$^2$ and 1060 µm/s/m$^2$ for 35% shade, 50% shade and open conditions, respectively. The recommended dose of fertilizer for *Brahmi* is 100:60:60 kg N, $P_2O_5$ and $K_2O$/ha (Anon, 2015). The organic manures were analyzed for their nutrient contents (Table 1) and organic manures required for each treatment were calculated on N basis. Runners of

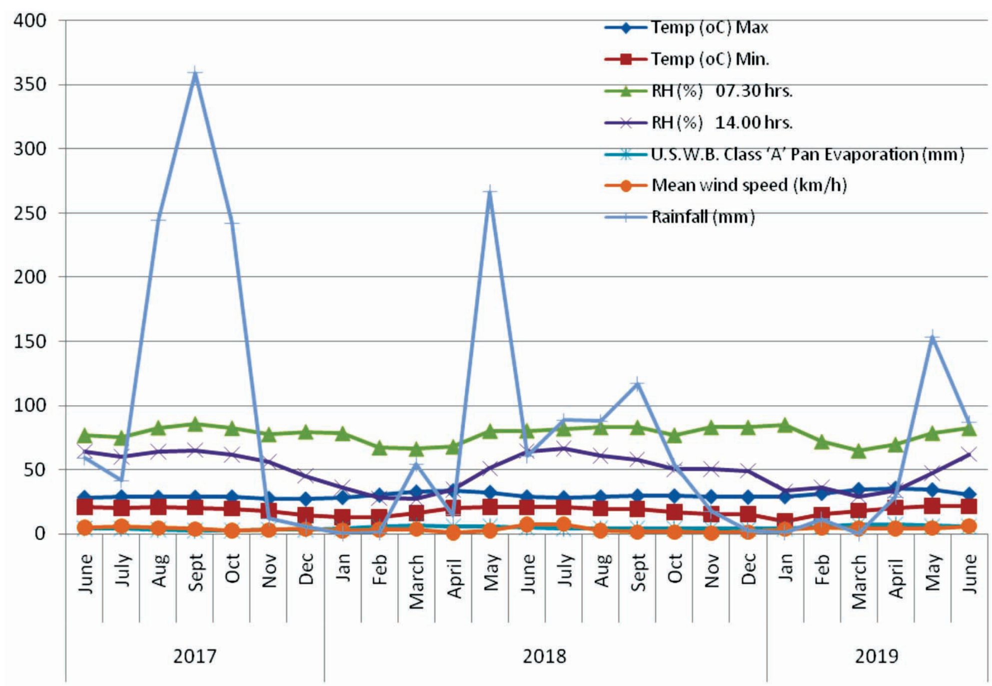



**Figure 2: Weather parameters of *Brahmi* experimental area during the period of experimentation**

**Table 1:** Physical and chemical properties of initial experimental soil and manures

| | Soil Properties |
|---|---|
| **Physical properties** | |
| Bulk density (Mg $m^{-3}$) | 1.33 |
| Particle Density (Mg $m^{-3}$) | 2.65 |
| Pore space (%) | 49.2 |
| **Electro-chemical and chemical properties** | |
| pH (1:2.5) | 6.96 |
| Electrical Conductivity ($dSm^{-1}$) | 0.34 |
| Organic Carbon (g $kg^{-1}$) | 7.65 |
| Available N (kg $ha^{-1}$) | 274 |
| Available P (kg $ha^{-1}$) | 36.4 |
| Available K (kg $ha^{-1}$) | 356 |
| Exchangeable Ca (cmol($p^+$) $kg^{-1}$) | 4.42 |
| Exchangeable Mg (cmol($p^+$) $kg^{-1}$) | 1.51 |
| DTPA Fe (mg $kg^{-1}$) | 9.64 |
| DTPA Mn (mg $kg^{-1}$) | 5.98 |
| DTPA Cu (mg $kg^{-1}$) | 2.55 |
| DTPA Zn (mg $kg^{-1}$) | 1.32 |
| **Manure** | **N (%)** |
| FYM | 0.58 |
| Vermicompost | 1.62 |

*Brahmi* were collected from University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru and were transplanted to the plot at a spacing of 20 × 20 cm. The plants were irrigated immediately after planting and on daily basis using drip laterals. Arka microbial consortium (AMC) @ 12.5 kg/ha/year was mixed with 500 kg FYM and uniformly applied to the beds of organic treatments. Arka Microbial Consortium is a carrier based product developed at ICAR-IIHR containing N Fixing, P and Zn solubilizing and plant growth promoting microbes in a single formulation (Anon., 2012).

**Plant growth and yield parameters**

The crop was first harvested at four months after transplanting (October, 2017) and subsequent harvestings were done during February, 2018, May, 2018, September, 2018, January, 2019, April, 2019 and June, 2019. The plants were harvested with the help of a sickle leaving a small basal portion behind to rejuvenate. After harvesting, plants were irrigated and ratoon crop started growing again and reached the harvesting stage in an interval of three to four months depending on the season. Observations on different growth (plant height, number of primary branches, number of secondary branches and plant spread), yield (fresh and dry herb yield) and quality parameters (active principle content / Bacoside content) were recorded at each harvesting. In a replication, ten plants in each plot were randomly chosen and recorded the observations. The values of different observations obtained from these plants were averaged to get the mean value.

**Estimation of active principle content**

***Standard preparation***

For preparation of standard solution, 1 mg of bacoside A reference standard (Natural Remedies Ltd., Bengaluru, India) was weighed accurately and transferred to a volumetric flask, followed by dissolution in 1 ml of methanol and then sonicating it for 5 min, cooled and made up the volume to 10 ml with methanol.

***Sample preparation***

Fresh herb was dried at 50 °C for 30 min, cooled to room temperature and then powdered. Accurately 3.0 g of powdered plant sample was transferred into 100 ml beaker and 45 ml of methanol (HPLC grade) was added to it. Beaker was then kept on water bath maintained at 90 °C with continuous stirring for 20 min. Thereafter, it was kept aside until it reached room temperature and the supernatant was collected in 100 ml volumetric flask. To the left over sample, again 30 ml of methanol was added and kept it on the water bath for 10 min. This procedure was repeated two-three times until whole content was extracted. The extract volume was finally made up to 100 ml using methanol, with proper shaking and allowed to settle. The supernatant was filtered using Nylon 0.2 µm, 13 mm nylon membrane and injected to HPLC.

***Sample analysis***

Estimation of total bacoside A (bacoside-A3, bacopaside-II, jujubogenin, bacopasaponin C) was done by HPLC - Shimadzu Nexera X2 HPLC with C-18, 4.6 mm I.D. × 250 mm, 5 µm column, 1.5 ml / min flow rate, 27 °C Column temperature, 205 nm (UV) Detector Wavelength, 20 µl of Injection volume and 55 min run time. The mobile phase was a gradient of acetonitrile (A) and water containing 0.05% (v/v) orthophosphoric acid (B). Stainless steel column (250 × 4.6 mm) packed with octadecylsilane bonded to porous silica (5 µm) was used. The flow rate was 1.5 mL/min, run time of 55 min and detection was done at 205 nm. Peak purity tests were carried out by comparing the peak areas and Rf values of standard with those present in the samples. Four compounds were identified namely; bacoside $A_3$, bacopasaponin C, bacopaside II and jujubogenin which were totalled and expressed as bacoside A (Figure 3). Bacoside content in the given sample was calculated using the following formula:

$$A = \frac{\text{Sample area} \times \text{Standard weight (mg)} \times \text{Sample dilution} \times \text{Purity of the standard}}{\text{Standard area} \times \text{Sample weight (mg)} \times \text{Standard dilution}}$$

Where, A = Bacoside A (Bacoside-A3, Bacopaside-II, Jujubogenin, Bacopasaponin C) content in w/w %.

### Statistical analysis

The analysis of variance was done in strip plot design for different observations recorded during seven harvests of the experiment using statistical software WASP 2.0 (ICAR-Central Coastal Agricultural Research Institute, Goa). Comparison among the two factors and interaction between the two factors were done for individual parameters for seven harvests. The results were assessed at 5% level of significance (P = 0.05). The critical difference (CD) values were calculated to compare the various treatment means.

## RESULTS AND DISCUSSION

### Growth parameters

#### *Plant height (cm)*

Plant height is one of the most significant indicators of plant growth and development under different shade and nutrient levels. Plant height amongst different shade levels was found to be significant only during I, II, VI and VII harvests, while in remaining harvests it was non-significant (Table 2). Similarly, for nutrient levels, it was found to be significant in most of the harvests, except for II and III harvests. For interaction effect, except for V and VII harvests it was non-significant. Maximum plant height was observed in 35% shade levels during I, II, VI and VII harvests (85.45 cm, 55.36 cm, 29.78 cm and 29.45 cm, respectively). Minimum plant height of 72.74 cm, 30.03 cm, 27.54 cm and 26.1 cm was observed in $S_3$ (open conditions) for I, II, VI and VII harvests, respectively. Among different nutrients treatment, the tallest plants were observed in 75% N equivalent through vermicompost - $N_5$ (86.11 cm), followed by 75% N equivalent through FYM - $N_2$ (85.56 cm) and 100% N equivalent through FYM - $N_3$ (82.6) during I harvesting. During VI and VII harvests, the highest plant height was observed in $N_8$ (37.09 cm and 30.33 cm, respectively). The minimum plant height was observed in treatment supplied with inorganic fertilizers only - $N_7$ (74.36 cm) during I harvesting, 75% N equivalent through vermicompost - $N_5$ (36.2 cm) during IV harvesting, 50% N equivalent through vermicompost - $N_4$ (28.07 cm) during V harvesting and 75% N equivalent through FYM - $N_2$ (24.14 and 24.29 cm) for VI and VII harvests, respectively. Among interaction effect, maximum plant height was registered in $S_2N_8$ (44.73 cm), $S_3N_8$ (44.53 cm), $S_3N_7$ (42.27 cm), $S_2N_7$ (42.38 cm) during V harvesting. It was minimum in $S_1N_2$ (24.4 cm), $S_2N_5$ (25.93 cm) and $S_3N_4$ (25.07 cm) during V harvesting and $S_3N_5$ (19.13 cm) and S3N4 (20.27 cm) during VII harvesting.

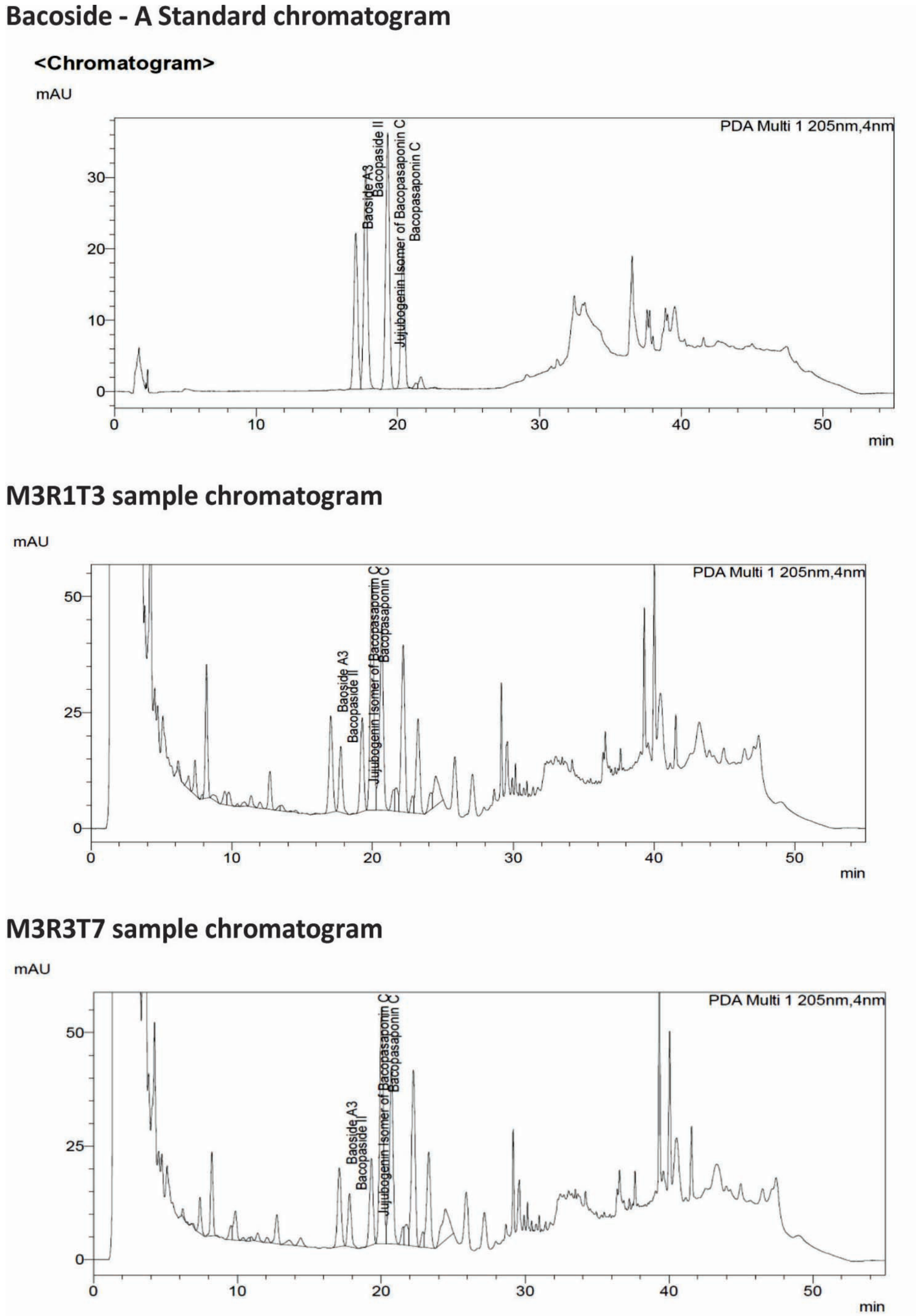
#### *Plant spread (cm²)*

Among different shade levels, plant spread was found to be significant only during IV, VI and VII harvests (Table 3). Maximum plant spread area was observed in 35% shade net (1880.74, 818.24 and 839.18 $cm^2$ during IV, VI and VII harvests, respectively) followed by 50% shade net. While, the minimum plant spread was in $S_3$ (open condition) which recorded plant spread of 1572.93, 663.54 and 441.07 $cm^2$, respectively during IV, VI and VII harvests. Among nutrients treatment $N_8$ (recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha) recorded maximum plant spread area of 2593.29, 1545.06, 1220.48 and 838.11 $cm^2$ during IV, V, VI and VII harvests, respectively. This was *on par* with $N_7$ (RDF only). Among interaction effect, $S_1N_8$, $S_1N_7$, $S_2N_7$ and $S_2N_8$ recorded maximum plant spread area, followed by $S_1N_5$, $S_1N_2$, $S_1N_4$ and $S_1N_5$.

#### *Number of primary branches*

Increase in the number of branches may increase the plant/soil coverage ratio, which in turn may increase the plant

**Figure 3: Bacoside - A Standard and sample chromatograms**




photosynthesis and assimilation. Among different shade levels, number of primary branches was significant only during I and V harvests. Number of primary branches was maximum (3.87 and 3.49) in 35% shade level ($S_1$) during I and V harvests, respectively (Table 4). This was minimum in $S_3$ (open condition) with 2.73 and 2.78 number of branches during I and V harvests. Among different nutrient levels, significant differences were observed during IV, V, VI and VII harvests. The highest number of primary branches (4.33, 3.71, 3.07 and 2.98) was recorded in INM treatment, $N_8$ during IV, V, VI and VII harvest, respectively. This was followed by $N_7$, $N_6$ and $N_5$. Least number of primary branches

**Table 2:** Plant height (cm) of *Brahmi* at different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| **Shade levels** | | | | | | | |
| $S_1$ - 35% shade | 85.45 | 55.36 | 42.48 | 44.13 | 31.17 | 29.78 | 29.45 |
| $S_2$ - 50% shade | 83.17 | 48.68 | 41.31 | 42.55 | 34.52 | 27.19 | 21.81 |
| $S_3$ - 100% sunlight | 72.74 | 30.03 | 41.56 | 41.24 | 31.26 | 27.54 | 26.10 |
| CD @ 5% | 4.66 | 11.07 | NS | NS | NS | 7.06 | 5.51 |
| **Nutrients** | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 79.07 | 43.73 | 41.09 | 39.64 | 29.58 | 26.12 | 25.13 |
| $N_2$ - 75% N equivalent through FYM | 85.56 | 44.00 | 41.76 | 39.85 | 28.14 | 24.14 | 24.29 |
| $N_3$ - 100% N equivalent through FYM | 82.60 | 45.59 | 43.00 | 40.60 | 31.89 | 26.72 | 25.85 |
| $N_4$ - 50% N equivalent through vermicompost | 78.24 | 43.93 | 41.44 | 39.76 | 29.29 | 25.66 | 25.89 |
| $N_5$ - 75% N equivalent through vermicompost | 86.11 | 45.55 | 40.98 | 36.20 | 30.24 | 24.66 | 25.49 |
| $N_6$ - 100% N equivalent through vermicompost | 81.20 | 46.03 | 42.35 | 41.75 | 28.07 | 25.81 | 26.60 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 74.36 | 44.90 | 41.89 | 52.87 | 39.66 | 35.16 | 28.71 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 76.49 | 43.80 | 41.73 | 50.47 | 41.66 | 37.09 | 30.33 |
| CD @ 5% | 5.44 | NS | NS | 4.38 | 4.52 | 5.25 | 2.32 |
| **Interaction of Shade x Nutrients** | | | | | | | |
| $S_1N_1$ | 86.47 | 57.67 | 43.60 | 38.53 | 27.80 | 28.40 | 29.73 |
| $S_1N_2$ | 85.60 | 54.53 | 45.60 | 39.40 | 24.40 | 23.73 | 31.67 |
| $S_1N_3$ | 87.07 | 58.91 | 38.87 | 40.47 | 32.13 | 27.47 | 28.87 |
| $S_1N_4$ | 84.93 | 51.91 | 39.53 | 42.27 | 29.87 | 29.47 | 29.67 |
| $S_1N_5$ | 94.67 | 56.51 | 42.47 | 37.60 | 38.73 | 26.67 | 29.67 |
| $S_1N_6$ | 92.27 | 54.22 | 43.33 | 46.53 | 26.40 | 26.93 | 26.73 |
| $S_1N_7$ | 73.60 | 55.69 | 47.00 | 53.80 | 42.27 | 38.07 | 32.60 |
| $S_1N_8$ | 79.00 | 53.4 | 39.4 | 41.80 | 44.53 | 37.53 | 34.27 |
| $S_2N_1$ | 79.20 | 48.00 | 35.67 | 43.27 | 34.02 | 25.27 | 24.67 |
| $S_2N_2$ | 92.87 | 47.53 | 36.87 | 42.27 | 31.82 | 23.53 | 23.40 |
| $S_2N_3$ | 83.73 | 49.53 | 47.53 | 42.07 | 34.27 | 28.60 | 24.60 |
| $S_2N_4$ | 78.80 | 48.20 | 42.60 | 41.93 | 32.93 | 22.20 | 21.73 |
| $S_2N_5$ | 90.73 | 52.67 | 41.40 | 34.93 | 25.93 | 24.07 | 21.67 |
| $S_2N_6$ | 82.00 | 49.73 | 43.53 | 41.00 | 30.07 | 24.00 | 25.87 |
| $S_2N_7$ | 76.60 | 45.00 | 38.20 | 52.53 | 42.38 | 32.73 | 28.53 |
| $S_2N_8$ | 81.40 | 48.80 | 44.65 | 55.07 | 44.73 | 37.13 | 30.73 |
| $S_3N_1$ | 71.53 | 25.53 | 44.00 | 37.13 | 26.93 | 24.70 | 21.00 |
| $S_3N_2$ | 78.20 | 29.93 | 42.80 | 37.87 | 28.20 | 25.17 | 20.80 |
| $S_3N_3$ | 77.00 | 28.33 | 42.60 | 39.27 | 29.27 | 24.09 | 21.07 |
| $S_3N_4$ | 71.00 | 31.67 | 42.20 | 35.07 | 25.07 | 25.31 | 20.27 |
| $S_3N_5$ | 72.93 | 27.47 | 39.07 | 36.07 | 26.07 | 23.24 | 19.13 |
| $S_3N_6$ | 69.33 | 34.13 | 40.20 | 37.73 | 27.73 | 26.49 | 21.20 |
| $S_3N_7$ | 72.87 | 34.00 | 40.47 | 52.27 | 34.33 | 34.67 | 25.00 |
| $S_3N_8$ | 69.07 | 29.20 | 41.13 | 54.53 | 35.73 | 36.61 | 26.00 |
| CD @ 5% (SxN) | NS | NS | NS | NS | 7.83 | NS | 3.93 |

**Table 3:** Plant spread (cm$^2$) of *Brahmi* during different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| **Shade levels** | | | | | | | |
| $S_1$ - 35% shade | 4054.10 | 3161.32 | 1407.80 | 1880.74 | 934.21 | 818.24 | 839.18 |
| $S_2$ - 50% shade | 4665.12 | 2365.54 | 1311.47 | 1757.67 | 1057.68 | 723.39 | 619.19 |
| $S_3$ - 100% sunlight | 4236.79 | 1195.45 | 1288.58 | 1572.93 | 796.31 | 663.54 | 441.07 |
| CD @ 5% | NS | NS | NS | 123.2 | NS | 122.95 | 347.34 |
| **Nutrients** | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 4459.47 | 1986.44 | 1408.13 | 1434.56 | 748.92 | 589.71 | 612.26 |
| $N_2$ - 75% N equivalent through FYM | 4545.73 | 2054.56 | 1344.51 | 1524.87 | 686.82 | 522.91 | 611.42 |
| $N_3$ - 100% N equivalent through FYM | 4651.49 | 2742.73 | 1292.80 | 1514.11 | 861.75 | 660.39 | 563.29 |
| $N_4$ - 50% N equivalent through vermicompost | 3662.00 | 2090.00 | 1385.00 | 1521.47 | 727.23 | 611.48 | 566.49 |
| $N_5$ - 75% N equivalent through vermicompost | 4460.33 | 2377.78 | 1224.02 | 1302.05 | 819.12 | 548.66 | 513.65 |
| $N_6$ - 100% N equivalent through vermicompost | 4294.31 | 2188.07 | 1426.07 | 1465.42 | 698.37 | 583.23 | 593.04 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 4069.51 | 2236.69 | 1265.44 | 2541.13 | 1347.93 | 1050.22 | 766.93 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 4406.51 | 2249.89 | 1341.62 | 2593.29 | 1545.06 | 1220.48 | 838.11 |
| CD @5 % | NS | NS | NS | 202.23 | 285.16 | 189.93 | 123.76 |
| **Interaction of Shade x Nutrients** | | | | | | | |
| $S_1N_1$ | 3899.00 | 2918.47 | 1582.60 | 1409.07 | 735.27 | 490.40 | 881.80 |
| $S_1N_2$ | 4551.00 | 2972.87 | 1570.47 | 1572.87 | 575.60 | 387.80 | 958.16 |
| $S_1N_3$ | 3947.80 | 3501.73 | 1323.00 | 1636.07 | 1076.40 | 809.60 | 757.73 |
| $S_1N_4$ | 3347.00 | 2641.6 | 1200.80 | 1807.67 | 801.93 | 678.49 | 814.12 |
| $S_1N_5$ | 3869.40 | 3393.8 | 1247.20 | 1670.27 | 1399.67 | 816.28 | 735.60 |
| $S_1N_6$ | 4555.27 | 3129.8 | 1522.40 | 1554.27 | 735.20 | 547.65 | 785.15 |
| $S_1N_7$ | 3776.33 | 3319.6 | 1598.93 | 2925.93 | 915.60 | 797.53 | 810.93 |
| $S_1N_8$ | 4487.00 | 3412.67 | 1217.00 | 2469.80 | 1234.03 | 979.31 | 969.92 |
| $S_2N_1$ | 4768.27 | 2129.73 | 1160.00 | 1683.87 | 1008.27 | 803.89 | 543.65 |
| $S_2N_2$ | 4402.20 | 2084.80 | 1030.27 | 1618.87 | 931.01 | 705.47 | 476.08 |
| $S_2N_3$ | 5248.93 | 2813.20 | 1260.47 | 1610.20 | 923.64 | 618.09 | 529.20 |
| $S_2N_4$ | 4034.87 | 2201.67 | 1681.13 | 1646.80 | 936.04 | 714.88 | 486.85 |
| $S_2N_5$ | 5297.73 | 2879.20 | 1246.53 | 1190.20 | 579.48 | 434.51 | 434.07 |
| $S_2N_6$ | 4765.13 | 2258.07 | 1593.93 | 1534.27 | 877.25 | 649.89 | 588.52 |
| $S_2N_7$ | 4290.87 | 2137.87 | 1042.93 | 2302.20 | 1531.08 | 1254.71 | 950.25 |
| $S_2N_8$ | 4512.93 | 2419.80 | 1476.53 | 2474.93 | 1674.68 | 1364.49 | 944.93 |
| $S_3N_1$ | 4711.13 | 911.13 | 1481.80 | 1210.73 | 503.23 | 474.83 | 411.32 |
| $S_3N_2$ | 4684.00 | 1106.00 | 1432.80 | 1382.87 | 553.84 | 475.45 | 400.03 |
| $S_3N_3$ | 4757.73 | 1913.27 | 1294.93 | 1296.07 | 585.20 | 553.49 | 402.93 |
| $S_3N_4$ | 3604.13 | 1426.73 | 1273.07 | 1109.93 | 443.73 | 441.07 | 398.49 |
| $S_3N_5$ | 4213.87 | 860.33 | 1178.33 | 1045.67 | 478.20 | 395.20 | 371.27 |
| $S_3N_6$ | 3562.53 | 1176.33 | 1161.87 | 1307.73 | 482.67 | 552.16 | 405.45 |
| $S_3N_7$ | 4141.33 | 1252.60 | 1154.47 | 2551.73 | 1597.12 | 1098.43 | 539.60 |
| $S_3N_8$ | 4219.60 | 917.20 | 1331.33 | 2678.67 | 1726.47 | 1317.65 | 599.47 |
| CD @ 5% (SxN) | NS | NS | NS | 338.28 | 438.73 | 189.93 | 182.00 |

**Table 4:** Number of primary branches of *Brahmi* during different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| **Shade levels** | | | | | | | |
| $S_1$ - 35% shade | 3.87 | 4.6 | 3.65 | 3.75 | 3.49 | 2.66 | 2.62 |
| $S_2$ - 50% shade | 3.14 | 4.20 | 3.54 | 3.81 | 3.19 | 2.47 | 2.56 |
| $S_3$ - 100% sunlight | 2.75 | 4.19 | 3.39 | 3.79 | 2.78 | 2.37 | 2.50 |
| CD @ 5% | 1.25 | NS | NS | NS | 0.39 | NS | NS |
| **Nutrients** | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 3.47 | 4.00 | 3.71 | 3.69 | 2.93 | 2.42 | 2.40 |
| $N_2$ - 75% N equivalent through FYM | 3.27 | 4.53 | 3.44 | 3.53 | 3.02 | 2.29 | 2.47 |
| $N_3$ - 100% N equivalent through FYM | 3.13 | 4.38 | 3.47 | 3.58 | 2.89 | 2.40 | 2.51 |
| $N_4$ - 50% N equivalent through vermicompost | 3.24 | 4.47 | 3.67 | 3.49 | 2.80 | 2.36 | 2.38 |
| $N_5$ - 75% N equivalent through vermicompost | 3.22 | 4.18 | 3.58 | 3.71 | 3.26 | 2.65 | 2.55 |
| $N_6$ - 100% N equivalent through vermicompost | 3.20 | 4.44 | 3.24 | 3.71 | 3.05 | 2.64 | 2.47 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 3.36 | 4.31 | 3.64 | 4.22 | 3.58 | 2.84 | 2.62 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 3.12 | 4.34 | 3.46 | 4.33 | 3.71 | 2.98 | 3.07 |
| CD @ 5% | NS | NS | NS | 0.189 | 0.267 | 0.312 | 0.293 |
| **Interaction of Shade x Nutrients** | | | | | | | |
| $S_1N_1$ | 3.93 | 4.07 | 3.87 | 3.67 | 3.47 | 2.53 | 2.40 |
| $S_1N_2$ | 3.93 | 5.47 | 3.80 | 3.47 | 3.27 | 2.27 | 2.80 |
| $S_1N_3$ | 3.20 | 4.93 | 3.40 | 3.60 | 3.33 | 2.53 | 2.53 |
| $S_1N_4$ | 4.20 | 5.13 | 3.27 | 3.47 | 3.20 | 2.67 | 2.60 |
| $S_1N_5$ | 4.00 | 4.2 | 3.87 | 3.87 | 3.93 | 2.53 | 2.73 |
| $S_1N_6$ | 3.67 | 4.4 | 3.40 | 3.53 | 3.07 | 2.47 | 2.40 |
| $S_1N_7$ | 4.20 | 4.33 | 4.00 | 4.27 | 3.73 | 3.13 | 2.47 |
| $S_1N_8$ | 3.80 | 4.27 | 3.60 | 4.13 | 3.93 | 3.13 | 3.00 |
| $S_2N_1$ | 3.60 | 3.87 | 3.87 | 4.00 | 3.20 | 2.53 | 2.47 |
| $S_2N_2$ | 2.87 | 4.07 | 3.13 | 3.53 | 3.20 | 2.40 | 2.27 |
| $S_2N_3$ | 3.40 | 4.07 | 3.60 | 3.60 | 2.80 | 2.40 | 2.27 |
| $S_2N_4$ | 3.00 | 4.13 | 3.80 | 3.60 | 2.80 | 2.13 | 2.20 |
| $S_2N_5$ | 3.13 | 4.33 | 3.53 | 3.53 | 3.13 | 2.33 | 2.73 |
| $S_2N_6$ | 3.20 | 4.47 | 3.40 | 3.80 | 3.00 | 2.27 | 2.53 |
| $S_2N_7$ | 3.07 | 4.27 | 3.53 | 4.20 | 3.53 | 2.73 | 2.80 |
| $S_2N_8$ | 2.87 | 4.40 | 3.47 | 4.20 | 3.87 | 2.93 | 3.20 |
| $S_3N_1$ | 2.87 | 4.07 | 3.40 | 3.47 | 2.47 | 2.20 | 2.33 |
| $S_3N_2$ | 3.00 | 4.07 | 3.40 | 3.60 | 2.60 | 2.20 | 2.33 |
| $S_3N_3$ | 2.80 | 4.13 | 3.40 | 3.53 | 2.53 | 2.27 | 2.73 |
| $S_3N_4$ | 2.53 | 4.13 | 3.93 | 3.40 | 2.40 | 2.27 | 2.33 |
| $S_3N_5$ | 2.53 | 4.00 | 3.33 | 3.73 | 2.73 | 2.20 | 2.20 |
| $S_3N_6$ | 2.73 | 4.47 | 2.93 | 3.73 | 2.73 | 2.27 | 2.47 |
| $S_3N_7$ | 2.80 | 4.33 | 3.40 | 4.53 | 3.47 | 2.67 | 2.60 |
| $S_3N_8$ | 2.70 | 4.35 | 3.30 | 4.33 | 3.33 | 2.87 | 3.00 |
| CD @ 5% (SxN) | 0.77 | NS | NS | NS | NS | NS | NS |

was observed in $N_4$ during I and II harvests (3.49 and 2.8), $N_2$ and $N_1$ (2.4) during VI and VII harvests. It is non-significant for the interaction effect except for I harvest.

***Number of secondary branches***

Number of secondary branches for different shade levels was significant only in I, II and IV harvests (Table 5). It was maximum in 35% shade - $S_1$ (68.69, 40.45 and 17.44, respectively) and minimum was observed in 100% sunlight condition - $S_3$ (43.89, 21.86 and 16.73, respectively). Among nutrient combinations, significant differences were observed only during I, IV, V and VI harvests. Maximum number of secondary branches was found in INM treatment, $N_8$ (59.82, 38.18, 25.82 and 20.29, respectively) during I, IV, V and VI harvests. It was followed by $N_6$ and $N_2$ treatments. Interaction effect was found to be non-significant for all harvests, except I harvest, wherein maximum number of branches was observed in $S_1N_6$ (78.4) and $S_1N_4$ (75).

Different growth parameters of *Brahmi* were found maximum in 35% shaded conditions ($S_1$) followed by 50% shade ($S_2$) and all the parameters were lowest under open conditions ($S_3$). Light intensity and quality are the important factors that affect the crop physiology which in turn contribute for the growth and development of plants (Nilsen and Orcutt, 1996). Both excess and deficient light distributions can be considered as stress to integrated plant system. Plants grown in different light quality caused physiological, morphological (leaf size and thickness) and behaviour changes (leaf angel deciduousness, leaf movements). The effect of light quality on the geranium (cv. Century Rose) showed that the solid spectral filter 101 recorded maximum plant height (24.2 cm), internodal length (1.68 cm) and leaf fresh weight (50.79 g/ plant) in geranium (Khattak *et al*., 2011). In Black pepper, different shade levels (75 % and 50 %) resulted in maximum leaf area, longer shoot, better rooting %, and maximum dry weight of roots, leaves and shoots (Seneviratne *et al*., 1985). Whereas, shade level of 70 % enhanced the plant height (25.6 cm) in certain medicinal plants like Vasaka (*Adathoda vasaka*) and Plumbago (*Plumbago zeylanica*) that are considered as shade tolerant plants (Neerakkal *et al*., 2001). In *Centella asiatica*, variety Nakhon Si Thammarat recorded highest leaf area of 14.73 $cm^2$ under photosynthesis photon flux density of 93.3 µmol $m^{-2}s^{-1}$ compared to 933.1(11.21$cm^2$) and 362.6 µmol $m^{-2}s^{-1}$ (13.87 $cm^2$) (Srithongkul, 2011). High light intensities showed damaging effect on the chlorophyll in *Pongamia pinnata*, whereas, plants grown under very low level of shade had minimum chlorophyll a/b ratio (Naidu and Swamy, 1993).

For the nutritional trial, INM treatment, $N_8$ (Recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha) recorded better growth parameters which was *on par* with the application of 100% N equivalent through FYM + AMC @ 5 kg/acre/year. It was observed that cation exchange capacity of soil increased by addition of organic manure thus facilitating in continuous supply of both macro- and micro-nutrients for a longer period which improves the plant growth. Incorporation of organic manures also improves the soil physical, chemical, and biological properties which in turn improve the water and nutrient availability, organic matter content and consequently increasing the plant growth parameters (Al-Fraihat, 2011). FYM has favourable effect on soil physical, chemical and biological factors that determine the productivity and fertility status of soil and supply nutrients in available form, resulting in higher crop yield and productivity. Similarly in Assam conditions, addition of organic manure resulted in faster spread and ground coverage of *Brahmi* and use of enriched compost @ 2 t/ha was determined as optimum (Baruah *et al.,* 2014). Singh, *et al.* (2007) reported the application of 75 kg N + 5 t/ha FYM recorded significantly higher mean crop growth rate with maximum number of leaves, branches spreading and yield in *Brahmi* at Pantnagar (Uttarakhand). Joy *et al*. (2005) in *Curculigo orchioides*, Sudhakara (2005) in *Coleus barbatus*, Charan Kumar (2009) in stevia, Jacoub (1999) in *Ocimum basilicum* and *Thymus vulgaris,* Gajbhiye *et al.* (2013) in lemongrass and Hussain (2002) on *Majorana hortensis* have also reported superiority of organic manures alone or in combination with chemical fertilizers for growth parameters.

Among the organic treatments, highest plant height was observed in 75% N equivalent through vermicompost. This could be attributed to vermicompost, which apart from increasing the population of microbes, also provides sufficient energy for them to remain active. It also provides vital macro-nutrients such as N, P, K, Ca, Mg and micro

**Table 5:** Number of secondary branches of *Brahmi* during different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| **Shade levels** | | | | | | | |
| $S_1$ - 35% shade | 68.69 | 40.45 | 33.22 | 33.63 | 19.82 | 17.44 | 17.38 |
| $S_2$ - 50% shade | 50.83 | 38.73 | 27.25 | 29.84 | 22.52 | 16.28 | 15.78 |
| $S_3$ - 100% sunlight | 43.89 | 21.86 | 23.83 | 27.75 | 20.62 | 16.73 | 14.82 |
| CD @ 5% | 2.87 | 4.11 | NS | NS | NS | 3.876 | NS |
| **Nutrients** | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 52.62 | 35.20 | 25.09 | 29.58 | 19.13 | 14.69 | 14.04 |
| $N_2$ - 75% N equivalent through FYM | 51.44 | 33.69 | 25.89 | 29.58 | 20.16 | 15.51 | 15.71 |
| $N_3$ - 100% N equivalent through FYM | 51.24 | 32.89 | 28.49 | 27.58 | 18.80 | 16.49 | 15.33 |
| $N_4$ - 50% N equivalent through vermicompost | 52.15 | 34.87 | 30.55 | 26.24 | 18.78 | 15.42 | 15.89 |
| $N_5$ - 75% N equivalent through vermicompost | 55.14 | 35.24 | 31.40 | 27.62 | 19.87 | 16.29 | 15.56 |
| $N_6$ - 100% N equivalent through vermicompost | 59.56 | 32.11 | 29.49 | 28.11 | 20.18 | 16.04 | 15.65 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 53.60 | 32.73 | 26.87 | 36.36 | 25.18 | 19.80 | 16.56 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 59.82 | 32.71 | 27.00 | 38.18 | 25.82 | 20.29 | 19.20 |
| CD @ 5% | 8.71 | NS | NS | 3.28 | 2.59 | 1.575 | NS |
| **Interaction of Shade x Nutrients** | | | | | | | |
| $S_1N_1$ | 56.27 | 41.93 | 19.20 | 33.33 | 17.53 | 16.20 | 14.40 |
| $S_1N_2$ | 57.13 | 42.53 | 21.53 | 32.67 | 17.67 | 14.47 | 19.00 |
| $S_1N_3$ | 45.53 | 38.33 | 24.20 | 31.20 | 16.00 | 17.20 | 17.07 |
| $S_1N_4$ | 75.80 | 40.33 | 27.93 | 29.80 | 18.13 | 17.00 | 17.53 |
| $S_1N_5$ | 71.47 | 49.13 | 23.00 | 32.00 | 23.67 | 18.73 | 18.60 |
| $S_1N_6$ | 78.40 | 33.93 | 25.27 | 29.53 | 19.00 | 14.73 | 16.07 |
| $S_1N_7$ | 72.13 | 39.33 | 28.27 | 42.80 | 24.00 | 21.73 | 15.87 |
| $S_1N_8$ | 66.80 | 38.07 | 21.20 | 37.67 | 22.53 | 19.47 | 20.47 |
| $S_2N_1$ | 53.00 | 43.00 | 23.47 | 30.47 | 21.33 | 14.33 | 14.53 |
| $S_2N_2$ | 45.60 | 39.20 | 23.73 | 30.00 | 23.07 | 16.67 | 14.27 |
| $S_2N_3$ | 63.73 | 39.73 | 26.40 | 26.60 | 21.80 | 17.00 | 15.53 |
| $S_2N_4$ | 37.33 | 37.87 | 31.33 | 26.40 | 20.67 | 13.33 | 16.60 |
| $S_2N_5$ | 51.07 | 38.27 | 25.67 | 24.13 | 17.13 | 15.67 | 14.40 |
| $S_2N_6$ | 59.00 | 37.13 | 36.00 | 28.13 | 21.73 | 16.20 | 15.60 |
| $S_2N_7$ | 49.47 | 34.73 | 23.80 | 36.33 | 25.53 | 17.00 | 16.53 |
| $S_2N_8$ | 47.40 | 39.93 | 27.60 | 36.67 | 28.93 | 20.00 | 18.80 |
| $S_3N_1$ | 44.20 | 20.67 | 32.60 | 24.93 | 18.53 | 13.53 | 13.20 |
| $S_3N_2$ | 51.60 | 19.33 | 32.40 | 26.07 | 19.73 | 15.40 | 13.87 |
| $S_3N_3$ | 44.47 | 20.60 | 34.87 | 24.93 | 18.60 | 15.27 | 13.40 |
| $S_3N_4$ | 43.33 | 26.40 | 32.40 | 22.53 | 17.53 | 15.93 | 13.53 |
| $S_3N_5$ | 42.87 | 18.33 | 45.53 | 26.73 | 18.80 | 14.47 | 13.67 |
| $S_3N_6$ | 41.27 | 25.27 | 27.20 | 26.67 | 19.80 | 17.20 | 15.27 |
| $S_3N_7$ | 39.20 | 24.13 | 28.53 | 35.40 | 26.00 | 20.67 | 17.27 |
| $S_3N_8$ | 44.20 | 20.13 | 32.20 | 34.73 | 26.00 | 21.40 | 18.33 |
| CD @ 5% (SxN) | 18.93 | NS | NS | NS | NS | NS | NS |

nutrients such as Fe, Cu, Mn, Zn, and Mo. Improved growth parameters might also be due to the enhanced availability of nutrients and production of growth promoting substances that caused cell elongation and multiplication as indicated by Patil *et al.* (2007).

**Yield parameters (t/ha)**

***Fresh herb yield (t/ha)***

Significantly highest fresh herb yield per hectare was obtained during I, II, III, VI and VII harvests with different shade and nutrient levels (Table 6). Among different shade levels tried, 35% shade net ($S_1$) recorded highest fresh herb yield (17.61, 19.33, 7.44 and 6.6 t/ha), followed by $S_2$ (50% shade condition). Whereas, the lowest fresh herb yield was recorded in open condition (11.48, 15.20, 3.94 and 4.36 t/ha, respectively during I, II, III, VI and VII harvests). Cumulative fresh herb yield of seven harvests was recorded in $S_1$ (94.66 t/ha) followed by $S_2$ (86.22 t/ha) and least was in $S_3$ (77.08 t/ha).

Amongst different nutrients levels tried, significant differences were observed during I, III, IV and VII harvests. Integrated nutrient management treatment $N_8$ consisting of both FYM and chemical fertilizers (100:60:60 kg NPK/ha) recorded highest fresh herb yield (16.65, 18.82, 31.22 and 6.18 t/ha, respectively during I, III, IV and VII harvests). This was followed by the treatment $N_7$ (recommended dose of fertilizers alone- 100:60:60 kg NPK/ha) which recorded 16.19, 18.42, 29.98 and 6.06 t/ha, respectively during I, III, IV and VII harvests. Whereas, $N_1$ (50% N equivalent through FYM) recorded least fresh herb yield (12.87, 15.03, 18.42 and 4.64 t/ha, respectively during I, III, IV and VII harvests). Cumulative fresh herb yield of seven harvests was also recorded highest in INM treatment $N_8$ (99.99 t/ha), which was followed by the treatments supplied with RDF (100:60:60 kg NPK/ha) - $N_7$ (96.32 t/ha), 100% N equivalent through FYM - $N_3$ (89.53 t/ha) and 75% N equivalent through vermicompost - $N_5$ (84.76 t/ha) and least was in 50% N equivalent through FYM - $N_1$ (75.75 t/ha).

The higher fresh biomass yield with combined application of full dose of FYM and recommended fertilizers is due to more contribution of yield attributes like plant height, number of leaves, plant spread, number of primary branches and secondary branches. Application of chemical fertilizers with FYM and biofertilizers helps in mineralization of nutrients and maintenance of soil moisture availability in the field. It also provides optimum physical condition to the soil by improving porosity and water holding capacity which proliferate root density. Higher root growth with combined application of FYM + NPK leads to higher nutrient uptake and thus more yield in *Brahmi*. Similar results were also reported by Bandyopadhyay *et al.* (2010) in soy bean.

Interaction effect was found to be significant only during IV and V harvests. $S_1N_8$ recorded the maximum fresh herb yield (38.97 and 9.78 t/ha, respectively during IV and V harvests). This was followed by $S_1N_7$ (27.17 and 9.55 t/ha), $S_2N_8$, $S_2N_7$, $S_3N_8$, $S_3N_7$ etc. Maximum cumulative fresh herb yield of seven harvests was also recorded in $S_1N_8$ (108.4 t/ha), followed by $S_1N_7$ (99.68 t/ha), $S_1N_5$ (91.68 t/ha), $S_1N_3$ (97.1 t/ha), $S_3N_8$ (89.25 t/ha), $S_2N_8$ (86.1 t/ha).

***Dry herb yield (t/ha)***

Significantly highest dry herb yield per hectare was recorded during I and V harvests only for the different shade levels (Table 7). Among different shade levels tried, 35% shade net ($S_1$) recorded highest dry herb yield (1.90 and 1.2 t/ha during I and V harvests, respectively), followed by $S_2$ (50% shade condition). Whereas, the lowest dry herb yield was recorded in full sunlight (100% sunlight) (1.27 and 0.76 t/ha during I and V harvests, respectively). Cumulative dry herb yield of seven harvests was recorded in $S_1$ (15.29 t/ha) followed by $S_2$ (14.58 t/ha) and least was recorded in $S_3$ (13.16 t/ha).

Amongst different nutrients levels tried, significant differences were observed during I, IV and VII harvests. INM treatment (10 t FYM/ha + RDF (100:60:60 kg NPK/ha) recorded maximum dry herbage yield (1.94, 4.8 and 1.27 t/ha, respectively during I, IV and VII harvests). This was *at par* with $N_7$ (RDF only - 100:60:60 kg NPK/ha) and $N_3$ (100% N equivalent through FYM). Whereas, the treatment 50% N equivalent through FYM ($N_1$) recorded least dry herbage yield (1.28, 3.23 and 1.23 t/ha, respectively during I, IV and VII harvests). Cumulative dry herb yield of seven harvests was also recorded maximum in INM treatments - $N_8$ (16.35 t/ha), which was on par with $N_7$ (RDF (100:60:60 kg NPK/ha) - 16.16 t/ha and $N_3$ (100% N equivalent through FYM) - 16.00 t/ha.

**Table 6:** Fresh herb yield (t/ha) of *Brahmi* during different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | Total |
| **Shade levels** | | | | | | | | |
| $S_1$ - 35% shade | 17.61 | 15.67 | 19.33 | 23.76 | 3.95 | 7.74 | 6.6 | 94.66 |
| $S_2$ - 50% shade | 15.21 | 15.24 | 15.94 | 21.97 | 6.78 | 5.06 | 6.02 | 86.22 |
| $S_3$ - 100% sunlight | 11.84 | 14.25 | 15.20 | 20.68 | 6.81 | 3.94 | 4.36 | 77.08 |
| CD @ 5% | 5.65 | NS | 2.711 | NS | NS | 3.55 | 1.09 | 7.72 |
| **Nutrients** | | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 12.87 | 14.89 | 15.03 | 18.42 | 5.10 | 4.80 | 4.64 | 75.75 |
| $N_2$ - 75% N equivalent through FYM | 15.31 | 15.87 | 16.52 | 20.39 | 5.79 | 4.47 | 4.90 | 83.25 |
| $N_3$ - 100% N equivalent through FYM | 17.78 | 17.04 | 18.02 | 20.78 | 5.73 | 4.26 | 5.92 | 89.53 |
| $N_4$ - 50% N equivalent through vermicompost | 13.17 | 15.54 | 17.19 | 18.94 | 5.80 | 3.73 | 5.07 | 79.44 |
| $N_5$ - 75% N equivalent through vermicompost | 14.07 | 15.54 | 17.69 | 20.20 | 6.49 | 4.81 | 5.96 | 84.76 |
| $N_6$ - 100% N equivalent through vermicompost | 14.04 | 16.85 | 14.47 | 19.85 | 6.73 | 5.93 | 5.01 | 82.88 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 16.19 | 13.66 | 18.42 | 29.98 | 5.84 | 6.17 | 6.06 | 96.32 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 16.65 | 15.69 | 18.82 | 31.22 | 5.30 | 6.13 | 6.18 | 99.99 |
| CD @ 5% | 4.23 | NS | 2.369 | 5.262 | NS | NS | 1.37 | 8.79 |
| **Interaction of Shade x Nutrients** | | | | | | | | |
| $S_1N_1$ | 13.28 | 16.07 | 20.99 | 21.27 | 4.19 | 8.08 | 4.00 | 87.88 |
| $S_1N_2$ | 15.89 | 15.45 | 19.76 | 21.99 | 3.87 | 8.9 | 3.68 | 89.54 |
| $S_1N_3$ | 22.97 | 18.75 | 21.11 | 19.85 | 4.05 | 6.53 | 3.84 | 97.1 |
| $S_1N_4$ | 14.98 | 15.2 | 18.54 | 19.76 | 4.02 | 5.12 | 3.9 | 81.52 |
| $S_1N_5$ | 18.97 | 16.54 | 19.57 | 22.12 | 3.74 | 7.15 | 3.59 | 91.68 |
| $S_1N_6$ | 15.78 | 14.63 | 20.73 | 18.97 | 3.4 | 6.83 | 3.23 | 83.57 |
| $S_1N_7$ | 20.03 | 14.5 | 17.59 | 27.17 | 4.42 | 9.55 | 6.42 | 99.68 |
| $S_1N_8$ | 18.98 | 14.21 | 16.35 | 38.97 | 3.93 | 9.78 | 6.18 | 108.4 |
| $S_2N_1$ | 10.61 | 13.66 | 17.6 | 20.55 | 7.93 | 4.03 | 5.84 | 80.22 |
| $S_2N_2$ | 12.07 | 16.28 | 15.91 | 23.25 | 4.93 | 4.52 | 4.8 | 81.76 |
| $S_2N_3$ | 11.54 | 16.81 | 17.59 | 18.9 | 7.48 | 4.49 | 7.34 | 84.15 |
| $S_2N_4$ | 13.21 | 16.93 | 15.91 | 18.93 | 6.25 | 4.17 | 6.09 | 81.49 |
| $S_2N_5$ | 10.23 | 14.03 | 15.58 | 19.77 | 9.12 | 4.45 | 8.97 | 82.15 |
| $S_2N_6$ | 11.28 | 15.74 | 17.4 | 21.05 | 5.1 | 5.17 | 6.96 | 82.7 |
| $S_2N_7$ | 13.5 | 16.48 | 12.42 | 23.14 | 5.43 | 6.08 | 5.45 | 82.5 |
| $S_2N_8$ | 17.25 | 14.5 | 13.07 | 25.71 | 7.06 | 2.41 | 6.1 | 86.1 |
| $S_3N_1$ | 11.71 | 16.9 | 15.5 | 14.73 | 6.19 | 2.28 | 6.07 | 73.38 |
| $S_3N_2$ | 14.9 | 14.8 | 14.08 | 15.79 | 8.71 | 1.74 | 5.53 | 75.55 |
| $S_3N_3$ | 16.16 | 15.45 | 16.85 | 16.57 | 6.9 | 2.07 | 6.1 | 80.1 |
| $S_3N_4$ | 13.00 | 14.62 | 15.45 | 14.5 | 5.9 | 1.59 | 5.76 | 70.82 |
| $S_3N_5$ | 11.3 | 11.98 | 12.59 | 22.03 | 6.23 | 6.31 | 6.57 | 77.01 |
| $S_3N_6$ | 14.05 | 14.17 | 17.27 | 15.81 | 6.7 | 1.8 | 6.33 | 76.13 |
| $S_3N_7$ | 16.09 | 15.2 | 17.74 | 16.74 | 6.47 | 1.07 | 6.57 | 79.88 |
| $S_3N_8$ | 15.4 | 15.37 | 14.53 | 24.07 | 6.54 | 6.54 | 6.8 | 89.25 |
| CD @ 5% (SxN) | NS | NS | NS | 6.212 | NS | NS | 2.52 | |

**Table 7:** Dry herb yield (t/ha) of *Brahmi* for different harvests as influenced by shade and nutrients

| Treatments | Harvests | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII | Total |
| **Shade levels** | | | | | | | | |
| $S_1$ - 35% shade | 1.9 | 3.3 | 2.98 | 3.56 | 1.20 | 1.17 | 1.18 | 15.29 |
| $S_2$ - 50% shade | 1.66 | 3.3 | 3.02 | 4.12 | 1.09 | 0.65 | 0.74 | 14.58 |
| $S_3$ - 100% sunlight | 1.27 | 3.23 | 2.48 | 3.53 | 0.76 | 0.82 | 1.07 | 13.16 |
| CD @ 5% | 0.59 | NS | NS | NS | 0.19 | NS | NS | 0.64 |
| **Nutrients** | | | | | | | | |
| $N_1$ - 50% N equivalent through FYM | 1.28 | 3.06 | 3.04 | 3.23 | 1.1 | 0.83 | 0.88 | 13.42 |
| $N_2$ - 75% N equivalent through FYM | 1.50 | 3.02 | 2.66 | 3.69 | 0.9 | 0.65 | 1.17 | 13.59 |
| $N_3$ - 100% N equivalent through FYM | 1.74 | 3.52 | 2.9 | 4.4 | 1.16 | 1.05 | 1.23 | 16.00 |
| $N_4$ - 50% N equivalent through vermicompost | 1.43 | 3.49 | 3.1 | 3.54 | 0.98 | 0.72 | 0.96 | 14.22 |
| $N_5$ - 75% N equivalent through vermicompost | 1.67 | 3.09 | 2.42 | 4.21 | 0.83 | 1.11 | 1.12 | 14.45 |
| $N_6$ - 100% N equivalent through vermicompost | 1.54 | 2.96 | 2.86 | 3.26 | 1.01 | 1.15 | 0.99 | 13.77 |
| $N_7$ - RDF (100:60:60 kg NPK/ha) | 1.78 | 3.46 | 3.04 | 4.43 | 1.07 | 1.18 | 1.2 | 16.16 |
| $N_8$ - RDF (100:60:60 kg NPK/ha) +FYM (10 t /ha) | 1.94 | 3.62 | 2.59 | 4.80 | 1.09 | 1.04 | 1.27 | 16.35 |
| CD @ 5% | 0.44 | NS | NS | 3.74 | NS | NS | 0.39 | 0.47 |
| **Interaction of Shade x Nutrients** | | | | | | | | |
| $S_1N_1$ | 1.53 | 3.01 | 2.94 | 2.79 | 0.95 | 0.59 | 0.93 | 12.74 |
| $S_1N_2$ | 1.7 | 2.59 | 2.97 | 3.21 | 0.58 | 1.91 | 0.56 | 13.52 |
| $S_1N_3$ | 1.88 | 4.03 | 3.24 | 3.7 | 1.03 | 1.04 | 0.75 | 15.67 |
| $S_1N_4$ | 1.64 | 2.83 | 3.33 | 3.29 | 0.66 | 1.09 | 0.64 | 13.48 |
| $S_1N_5$ | 1.74 | 3.24 | 2.86 | 2.92 | 0.93 | 1.21 | 0.98 | 13.88 |
| $S_1N_6$ | 1.76 | 3.58 | 2.98 | 2.97 | 0.74 | 0.91 | 0.71 | 13.65 |
| $S_1N_7$ | 1.96 | 3.25 | 2.45 | 4.62 | 1.17 | 1.1 | 1.15 | 15.70 |
| $S_1N_8$ | 2.02 | 3.85 | 2.78 | 5.59 | 0.63 | 1.16 | 0.61 | 16.64 |
| $S_2N_1$ | 1.3 | 2.92 | 2.54 | 4.01 | 0.75 | 0.44 | 0.73 | 12.69 |
| $S_2N_2$ | 1.13 | 2.16 | 2.78 | 3.84 | 1.14 | 0.85 | 1.12 | 13.02 |
| $S_2N_3$ | 1.45 | 3.87 | 2.15 | 3.59 | 0.86 | 0.79 | 0.84 | 13.55 |
| $S_2N_4$ | 1.41 | 3.53 | 2.42 | 3.31 | 1.07 | 0.51 | 1.04 | 13.29 |
| $S_2N_5$ | 1.12 | 2.88 | 2.45 | 3.08 | 1.45 | 0.97 | 1.44 | 13.39 |
| $S_2N_6$ | 1.21 | 2.74 | 2.07 | 3.57 | 0.77 | 0.99 | 0.76 | 12.11 |
| $S_2N_7$ | 1.71 | 3.27 | 2.75 | 4.01 | 0.55 | 0.8 | 0.53 | 13.62 |
| $S_2N_8$ | 1.91 | 3.41 | 3.17 | 3.5 | 0.99 | 0.56 | 1.02 | 14.56 |
| $S_3N_1$ | 1.27 | 3.00 | 3.09 | 3.04 | 1.12 | 0.39 | 0.74 | 12.65 |
| $S_3N_2$ | 1.89 | 3.83 | 3.00 | 3.02 | 0.8 | 0.35 | 0.58 | 13.47 |
| $S_3N_3$ | 1.53 | 3.42 | 3.24 | 2.63 | 1.43 | 0.6 | 0.67 | 13.52 |
| $S_3N_4$ | 1.41 | 3.5 | 3.02 | 3.27 | 0.98 | 0.33 | 0.66 | 13.17 |
| $S_3N_5$ | 1.64 | 2.89 | 2.57 | 4.14 | 1.02 | 0.31 | 1 | 13.57 |
| $S_3N_6$ | 1.58 | 2.84 | 2.4 | 2.21 | 1.68 | 1.13 | 0.65 | 12.49 |
| $S_3N_7$ | 1.62 | 3.58 | 2.48 | 3.52 | 0.8 | 0.9 | 0.69 | 13.59 |
| $S_3N_8$ | 1.71 | 3.93 | 2.86 | 3.29 | 0.97 | 0.75 | 0.72 | 14.23 |
| CD @ 5% (SxN) | 0.71 | NS | NS | NS | NS | NS | NS | |

Interaction effect of shade and nutrition on dry herbage yield per hectare was significant only during I harvest. Here also, the treatment $S_1N_8$ recorded the maximum dry herb yield (2.02 t/ha) which was *at par* with $S_1N_7$ (1.96 t/ha) and least was recorded in $S_2N_5$ (1.21). Cumulative dry herb yield of seven harvests was also recorded in $S_1N_8$ (16.64 t/ha), followed by $S_1N_7$ (15.70 t/ha), $S_1N_3$ (15.67 t/ha), $S_3N_8$ (14.23 t/ha), $S_3N_8$ (14.23 t/ha) and $S_1N_5$ (13.88 t/ha). Further, it was observed that there was a positive correlation between the weather parameters (Figure 2) to the growth and yield of *Brahmi* wherein the growth and yield parameters were highest in the harvests coincided with the monsoon season and it was less during the winter season.

From this study it is clear that *Brahmi* is a shade loving crop and 35% shaded conditions are optimum for obtaining maximum fresh and dry herbage yield. Similarly, Kumar *et al*. (2016) obtained the highest dry herbage yield (5.73 t/ha) and oil yield (36.82 kg/ha) of patchouli under shade with application of vermicompost (24 kg/plot) compared to that in open condition under teak (*Tectona grandis*) based agroforestry system. In mango ginger (*Curcuma amada*), rhizome yield under open and shaded conditions (25 %) were *on par* with each other (Jayachandran and Nair, 1998). *Bangladhonia* (*Eryngium foetidum*) grown under 50 % shade with the application of 161 kg N/ha increased the plant height (22.71 cm), leaves per plant (8.20) and fresh yield (55.96 t/ha) (Moniruzzaman *et al*., 2009).

Improvement in yield parameters may be due to the production of plant growth substances by the application of FYM which ultimately resulted in faster in cell division, multiplication and cell elongation in meristematic region of the plant (Sendur *et al.,* 1998). The FYM provides optimum physical environment for plant growth and development. It also increases the nutrient availability, porosity, water holding capacity and microbial population in the soil which helps in higher nutrient uptake and yield of *Brahmi*. Shirole *et al.* (2005) showed that application of FYM helped *Brahmi* in faster area coverage as a result of better branching and faster elongation of prostrate branches under Rahuri conditions. Similarly, maximum dry herbage yield of *Brahmi* was obtained by the application of enriched compost @ 2 t/ha which was followed by the treatment that received 2 t enriched compost having 25% w/w supplementation with FYM under Assam conditions (Baruah *et al.,* 2014).

It is also observed that organic manure application enhanced the fresh and dry weight of leaves compared with chemical fertilizer. Availability of more nutrients and their slow release can be attributed to its better efficacy. The similar results were also reported in Black Night Shade (*Solanum nigrum*), where the plants supplied with 75 % through fertilizers + 25% through poultry manure recorded better growth and yield parameters (Smitha *et al.,* 2010a). Smitha *et al.* (2010b) revealed that long pepper (*Piper longum* L.) is a organic manure loving crop and application of FYM 40 t + vermicompost 2 t + neem cake 2 t + bio fertilizers 10 kg/ha helped in realizing better growth, yield and quality parameters. Combined application of FYM with biofertilizers increased the herbage yield in *Indigofera tinctoria* (Sindhu *et al.,* 2016). Salman (2006) in *Ocimum basilicum* and Umesha *et al.* (2011b) in *Solanum nigrum,* Chand *et al.* (2012) in *Mentha arvensis* also reported the similar results. Further the application of microbial consortia (AMC) provides appreciable plant growth promoting rhizobacteria that facilitate the nutrient availability and uptake and eventually increase the yield in many horticultural crops (Anon., 2012).

**Effect of shade and nutrition on the active principle content of *Bacopa monnieri***

Effect of different shade and nutrition levels on active principle content of *Brahmi* was analyzed and presented in Figure 4A & 4B, respectively. Significant results were obtained only for Bacopasaponin C and Bacoside A. Rest of the components like Bacoside-A3, Bacoside II and Jujubojenin were found to be non-significant. Among different shade levels tried, highest and lowest Bacopasaponin C and Bacoside A contents were obtained with 100% sunlight (1.44 and 2.93%) and 35% shade (1.15 and 2.63 %), respectively. Among different nutrient levels tried, highest Bacopasaponin-C (1.18%) and Bacoside A content (2.97%) were obtained in the treatment with integrated application of recommended dose of fertilizers (100:60:60 kg NPK/ha) + FYM (10 t /ha), which was *on par* with $N_4$-50% N equivalent through vermicompost and $N_5$-75% N equivalent through vermicompost. However, the lowest content of Bacopasaponin C was obtained with $N_6$-100% N equivalent through vermicompost (1.03%) and Bacoside A was found in $N_1$ - 2.40 %. The Bacoside A

**Figure 4A: Effect of shade on active principle content of *Brahmi***

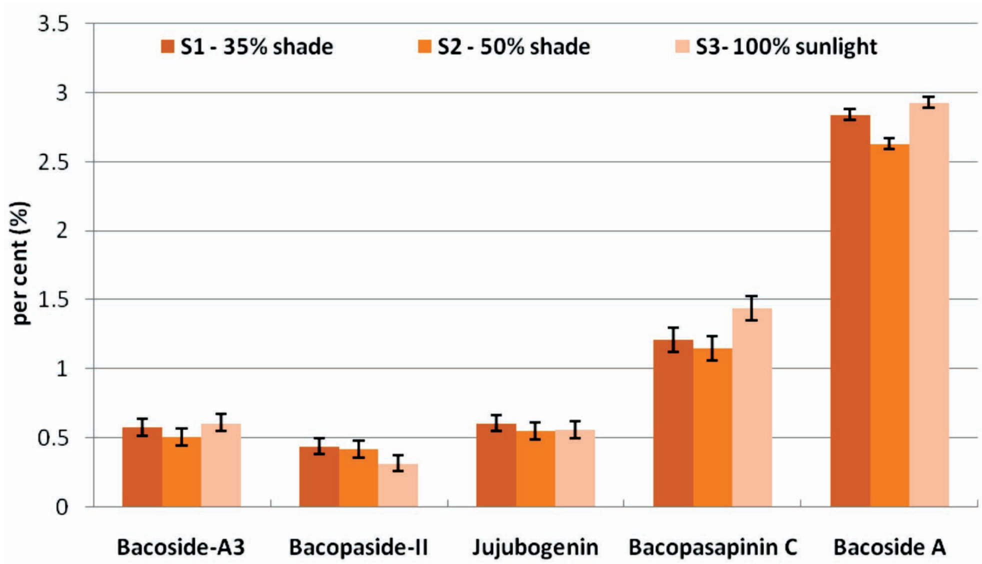
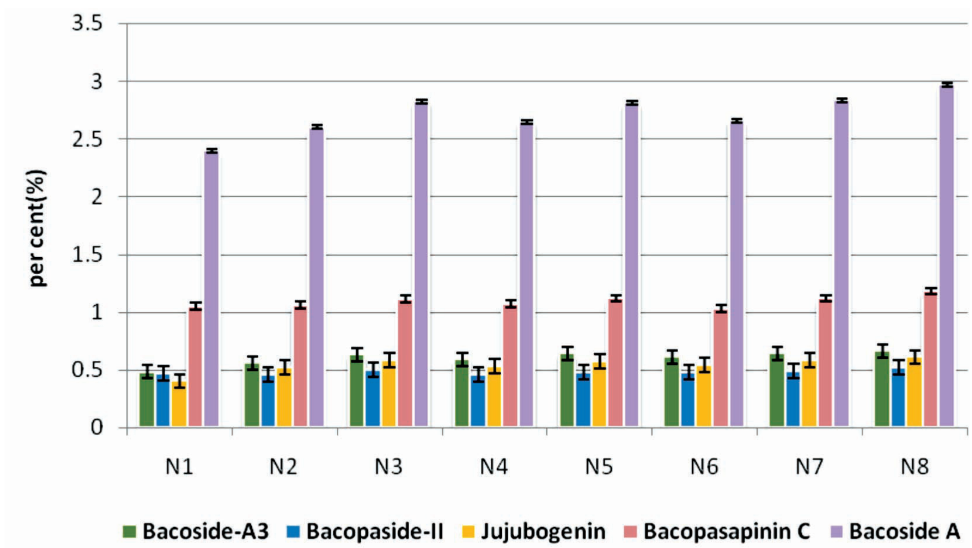



**Figure 4B: Effect of nutrition on active principle content of *Brahmi***




content in *Brahmi* sample showed highest in INM treatment $N_8$ - RDF (100:60:60 kg NPK/ha) + FYM (10 t /ha) which was *on par* with RDF only treatment $N_7$ - 2.83%, which was followed by organic treatments, $N_3$ - 2.82% and $N_5$ - 2.81%. However, all these contents were non-significant for interaction of shade and nutrient levels. Soil's macro and micro elements are enhanced by the application of organic fertilizers which plays an essential role in the plant growth and development that reflect on the vegetative mass and in the amount of active principle content.

Similar to results of the present study, harmful effect of shade on triterpenoids content has been reported in *C. asiatica* (Srithongkul, 2011). Higher asiaticoside content was recorded under high light intensity of 933.1µmol $m^{-2}$ $s^{-1}$ in all the three accessions *viz.* Nakhon Si Thammarat (2.77%), Rayong (2.80%) and Ubon Ratchathan (3.50%) than in low light intensity of 362.5 and 93.31µmol $m^{-2}s^{-1}$. Alkaloid content in leaves of *Tetracera scandens* L. was higher in full sun light than in shaded condition as the leaves at the open area had more sediment than in the shaded area (Setiawati *et al*., 2018). In *Aloe vera*, different light intensities such as full sun light, partial sun light (30 % full sun) and deep shade (10 % full sun) for 12 to 18 months affected the concentration of soluble carbohydrate and aloin in leaf exudates (Paez *et al*., 2000). Further, it was inferred that control of higher irradiance did not result in higher concentration of aloin.

In tall larkspur (*Delphinium barbeyi*), plants treated with short term shade (70 % reduction in sun light for three days) increased the alkaloid concentration than untreated plants (Ralphs *et al*., 1998). Salmore *et al*. (2001) observed increased alkaloid concentration in *Sanguinaria canadensis* at low light intensity. Kong *et al.* (2016) studied the effect of variation of light intensity on alkaloid content of *Mahonia bodinieri* and found that the estimated total yield of alkaloids was maximum in $I_{30}$ (30 % full light) and $I_{50}$ (50 % full light) compared to $I_{10}$ or $I_{100}$ due to the higher biomass production in partial shaded conditions.

Effect of organic nutrition alone or in combination with inorganic fertilizers on active principle content of many medicinal plants is well established. In *Ashwagandha* (*Withania somnifera*), maximum root alkaloid content of 0.139 and 0.140% was observed in JA-20 and JA-134, respectively due to the application of FYM at 5 t $ha^{-1}$ when compared with use of inorganic fertilizers (Maheshwari *et al.,* 2000). In *Ashwagandha*, inorganic fertilizer application @ 40:20:20 kg $N:P_2O_5:K_2O$ $ha^{-1}$ along with 2.5 t vermicompost and 5 t FYM + 20 kg $ZnSO_4$ resulted in maximum content of withanolide A (0.069 %), withanolide B (0.037 %), withaferin-A (0.065%) and total alkaloids (1.40%) (Shrivastava *et al.,* 2012). Principal constituents of basil oil *i.e.,* methyl chavicol (78.69%) and linalool (19.60 %) were higher with integrated use of 10 t vermicompost and 50:25:25 kg NPK per hectare (Anwar *et al.,* 2005). Seasonal variation has significant influence on plant growth and bacoside-A content in *Bacopa monnieri* accessions as reported by Mathur *et al* (2000).

In stevia, dry leaf yield during first (6.16 t/ha) and second year of cropping (4.34 t/ha), stevioside (7.8%) and rebaudioside contents (3.4%) were maximum with the treatment comprising of FYM (25 t/ha) + vermicompost (2 t/ha) + neem cake (1.0 t/ha) + bio-fertilizers (10 kg/ha) (Umesha *et al.,* 2011a). In Sacred basil (*Ocimum sanctum* Linn), maximum dry herb yield (6.30 t/ha), essential oil content (1.71%) and essential oil yield (10.79 kg/ha) was obtained with the application of 100% N equivalent through FYM + AMC (Smitha *et al.,* 2019). Similarly in *Ocimum basilicum,* Khalid *et al*. (2006) and Geetha *et al.* (2009) reported that application of organic manures significantly improved the essential oil content. In *Ocimum basillicum,* El-Naggar *et al.* (2015) reported enhancement in oil content which may be due to increase in number of oil glands or enlargement in oil glands or both of them which was resulted due to the use of organic manures and bio fertilizers. Vineeta *et al.* (2013) also reported an improvement in the essential oil content in the seeds of European dill (*Anethum graveolens* L.) by the application of farm yard manure. Younesian *et al*. (2013) also highlighted the effect of organic manures and biological fertilizers on improving the quality of fennel.

From the present investigation it is evident that *Brahmi* is a shade loving crop and growing it in 35% shaded conditions enhanced the growth and cumulative dry herb yield (15.29 t/ha). However, active principle content (Bacopasaponin C - 1.88% and Bacoside A - 2.93%) was maximum under open conditions. Among different nutrient levels tried, integrated application of organic manure and inorganic fertilizers [RDF (100:60:60 kg NPK/ha) + FYM (10 t /ha)] resulted in highest dry herbage yield (16.35 t/ ha) which was *on par* with the organic treatment with the application of 100% N equivalent through FYM + Arka microbial consortium (AMC) @ 12.5 kg/ha/year (16 t/ha). In the recent days, there is a growing awareness among the consumers regarding environmental supportive, quality and safe production of medicinal herbs for which organic cultivation is an alternative approach. In this regard, it has been proved by this study that *Brahmi* can be grown organically by supplementing 100% N equivalent through FYM under 35% shaded conditions and obtain cumulative dry herb yield to an extent of 16 t/ha and can reap premium price in the market.

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