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## Influence of photosynthetic bacteria and biochar on growth, yield and biochemical parameters of broccoli (*Brassica oleracea* var. *italica*)

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**Abstract**

The present experiment was conducted to determine the influence of photosynthetic bacteria and biochar on growth, yield and biochemical parameters of broccoli (*Brassica oleracea* var. *italica*) in the Department of Horticulture, Allahabad School of Agriculture, SHUATS, Allahabad (U.P) during the year 2017-2018. Ten treatments were included in the trial were viz; T<sub>0</sub> Control, T<sub>1</sub> (PSB 50L/ha + Biochar 20t/ha), T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha), T<sub>3</sub> (PSB 150L/ha + Biochar 50t/ha), T<sub>4</sub> (PSB 50L/ha + Biochar 30t/ha), T<sub>5</sub> (PSB 100L/ha + Biochar 50t/ha), T<sub>6</sub> (PSB 150L/ha + Biochar 20t/ha), T<sub>7</sub> (PSB 50L/ha + Biochar 50t/ha), T<sub>8</sub> (PSB 100L/ha + Biochar 20t/ha), T<sub>9</sub> (PSB 150L/ha + Biochar 30t/ha) and were tested in three replications. The experiment was laid out in simple R.B.D. Studies showed that, significant effect on the height of plant 90 DAT (65.83 cm), number of leaves 90 DAT (32.47), days to first visible curd (71.07 days), leaf area 90 DAT (588.09 cm<sup>2</sup>), leaf width 90DAT (20.42 cm), fresh weight of plant (995.75 g), fresh root weight of plant (105.5 g), dry weight of plant (193.6 g), dry root weight (39.47 g), head yield per plot (4.49 kg), bud or head weight (499.37 g), bud or head diameter (16.55 cm), head yield per hectare (14.98 t/ha), chlorophyll 'a' (1.74 mg/g/Fr.wt.), chlorophyll 'b' (1.59 mg/g/Fr.wt.), total chlorophyll (3.59 mg/g/Fr.wt.), total carotenoid (1.12 mg/g/Fr.wt.), leaf proline content (0.011 mg/g/Fr.wt.), vitamin C (mg/100g broccoli fresh head) (91.55 mg), gross return (Rs 374,500/ha), net return (Rs.260,050/ha), Benefit Cost ratio (3.27:1) was observed maximum in treatment T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha).

**Keywords:** broccoli, PSB, biochar, yield, growth, biochemical

**Introduction**

Broccoli (*Brassica oleracea* var. *italica*) belongs to family Brassicaceae. It is an edible green plant in the cabbage family whose large flowering head is eaten as a vegetable. The word broccoli comes from the Italian plural of broccolo, which means "the flowering crest of a cabbage", and is the diminutive form of broccolo, meaning "small nail" or "sprout". The optimum temperature range of 10-25 °C is ideal for proper growth of the crop. The nutritive value of broccoli per 100g is energy 141kJ, carbohydrates 6.64g, sugar 1.7g, dietary fiber 2.6g, fat 0.37g, protein 2.82g, vit A 9000IU, calcium 47mg, iron 0.73mg, phosphorous 66mg, thiamine 0.071mg, riboflavin 0.117mg, niacin 0.639mg, vit C 89.2mg. Broccoli Green magic (F1) hybrid plant produces medium size blue-green broccoli. The head averages 6 to 9 inches in diameter. It is very flavorful. This broccoli has very good uniformity and holding ability. This heat tolerant variety can be grown for summer or fall harvest. A cool-weather crop that can be grown in spring and fall everywhere, and even in winter in mild climates.

In addition to its economic importance, Epidemiological studies have shown that consumption of Brassica vegetables, including broccoli, reduces the risk of several types of cancers and cardiovascular disease mortality.

The excessive use of chemical fertilizers has caused tremendous harm to environment. So nowadays, the pursuit of quality, fresh, non-toxic and safe has become the trend of global agricultural production. Application of photosynthetic bacteria and biochar in farming is regarded as environmental friendly, and can be used to reduce excessive amount of chemical fertilizer application, and ensures a sustainable crop production. Photosynthetic bacteria, much like the name suggests, these micro-organisms are special types of bacteria that contain light absorbing pigments and reaction centers which make them capable of converting light energy into chemical energy. Photosynthetic bacteria (PSB) have been extensively used in agriculture to promote plant growth and to improve crop quality. Biochar is Charcoal used as a Soil conditioner or soil enhancer to increase fertility, prevent soil degradation. It improves soil fertility by retaining water and nutrients in soil, encouraging beneficial soil organisms and

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thereby reducing the need for additional use of fertilizers. Therefore, keeping in view the importance of photosynthetic bacteria and biochar, the present study was initiated to find out the influence of photosynthetic bacteria and biochar on growth, yield and biochemical parameters of broccoli (*Brassica oleracea* var. *italica*).

### Materials and methods

The present investigation entitled "Influence of Photosynthetic bacteria and Biochar on the growth, yield and biochemical parameters of broccoli (*Brassica oleracea* var. *italica*)" was carried out at Department of Horticulture, Allahabad School of Agriculture, Sam Higginbottom University of Agriculture, Technology and Science Allahabad (U.P) during the year 2017-2018. The experiment was laid out in Randomized Block Design comprising of ten treatments with one variety each replicated thrice. The seedlings of broccoli were sown separately in the nursery on the 17<sup>th</sup> September, 35 days old seedlings were transplanted in the Horticulture field in the month of 26<sup>th</sup> October 2017. The seedlings were transplanted in well moist soil. The first observation was taken at 30 days after transplanting (DAT) that was on 25<sup>th</sup> November, 2017. Subsequently rest of the observations were also recorded after every 30 days interval i.e. growth parameters, head formation and biochemical parameters. The crop was harvested on 25<sup>th</sup> January, 2018 which was the first harvest, then the second harvest and third harvest was done on 1<sup>st</sup> and 7<sup>th</sup> of February, 2018. The organic manure applied was vermicompost 20 t/ha which was well incorporated in the experimental field 10 days before transplanting of seedlings. The biochar was applied to the field before transplanting while PSB was given after every seven days after transplanting. Ten treatments were included in the trial were viz; T<sub>0</sub> Control, T<sub>1</sub> (PSB 50L/ha + Biochar 20t/ha), T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha), T<sub>3</sub> (PSB 150L/ha + Biochar 50t/ha), T<sub>4</sub> (PSB 50L/ha + Biochar 30t/ha), T<sub>5</sub> (PSB 100L/ha + Biochar 50t/ha), T<sub>6</sub> (PSB 150L/ha + Biochar 20t/ha), T<sub>7</sub> (PSB 50L/ha + Biochar 50t/ha), T<sub>8</sub> (PSB 100L/ha + Biochar 20t/ha), T<sub>9</sub> (PSB 150L/ha + Biochar 30t/ha).

### Result and discussion

The results of the investigation, regarding the effect of photosynthetic bacteria and biocharcoal on growth and yield and biochemical parameters of broccoli have been presented in tables and bar-diagrams wherever required. The result of the experiment has been presented under the following heading.

#### Growth parameters

The treatment significantly altered with all the growth parameters at all successive stage of growth. The treatment T<sub>2</sub>(PSB 100L/ha + Biochar 30t/ha) was observed maximum at all successive stage of growth (30, 60, 90 DAT) with plant

height (13.60cm, 24.87cm and 39.89 cm), number of leaves per plant (7.80, 23.73 and 32.47), leaf area (154.64 cm<sup>2</sup>, 391.29 cm<sup>2</sup> and 588.09 cm<sup>2</sup>), leaf width (7.43 cm, 15.53 cm and 20.42 cm), while plant biomass observation was taken as post harvest observation and recorded maximum in treatment T<sub>2</sub>(PSB 100L/ha + Biochar 30t/ha) i.e. fresh weight of plant (995.75 g), fresh root weight of plant (105.50 g), dry weight of plant (193.60 g) and dry root weight (39.47 g) followed by T<sub>9</sub> (PSB 150L/ha + Biochar 30t/ha) which is superior as compared to control. While, days to first visible curd was at (71.07 days). Application of photosynthetic bacteria generate higher yields by providing valuable nutrients to the plant and soil while biochar helped in the conditioning of the soil, increase in biomass, bettering the growth. PSB and Biochar improved the broccoli growth and growth parameters. The performance of the plants was better in treated treatments in comparison to the control. These similar findings were recorded by Upadhyay *et al.*, (2014) <sup>[10]</sup> in lettuce.

#### Yield parameters

The highest yield per plot was in treatment T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha) (4.49 kg), highest bud weight (499.37g), maximum bud diameter (16.55 cm), and maximum yield per hectare (14.98 t/ha) was also found in T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha) followed by T<sub>9</sub> PSB 150L/ha + Biochar 30t/ha and T<sub>8</sub> PSB 100L/ha + Biochar 20t/ha. Similarly, Jun *et al.*, (2002) reported that photosynthetic bacteria can increase the yield and quality of vegetables, may be due to photosynthetic bacteria metabolites rich in nutrients, rich in various vitamins. Trupiano *et al.*, (2017) also had a similar report that biochar helped in the conditioning of the soil, increase in biomass, bettering the growth.

#### Biochemical parameters

The treatment T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha) observed maximum chlorophyll 'a' (mg/g/Fr.wt.) (1.74 mg/g/Fr.wt.), chlorophyll 'b' (mg/g/Fr.wt.) (1.59 mg/g/Fr.wt.), total chlorophyll (mg/g/Fr.wt.) (3.59 mg/g/Fr.wt.), total carotenoid (mg/g/Fr.wt.) (1.12 mg/g/Fr.wt.), vitamin 'C' mg/100g (91.55 mg) followed by T<sub>9</sub> PSB 150L/ha + Biochar 30t/ha where as minimum findings were associated with T<sub>0</sub> Control as presented in table. While in leaf proline the least was observed with treatment T<sub>2</sub> (PSB 100L/ha + Biochar 30t/ha) i.e., (0.011 mg/g/Fr.wt.) followed by T<sub>9</sub> (PSB 150L/ha + Biochar 30t/ha) i.e. (0.019 mg/g/Fr.wt.) and the increased leaf proline content was in T<sub>0</sub> (control) which was (0.142 mg/g/Fr.wt.). Similarly, Jun *et al.*, (2002) reported that photosynthetic bacteria can use small molecular organic compounds to synthesize nutrients needed by crops, increase the ability of photosynthesis, and increase yield and quality of the product William *et al.*, (2015) and Hafeez *et al.*, (2017) also reported that biochar positively affects chlorophyll content, boost the total Photosynthetic performance index.

**Table 1:** Influence of photosynthetic bacteria and biochar on growth parameters of broccoli.

| Treatment symbol | Treatment combination        | Plant height (cm) |        |        | Number of leaves per plant |        |        |
|------------------|------------------------------|-------------------|--------|--------|----------------------------|--------|--------|
|                  |                              | 30 DAT            | 60 DAT | 90 DAT | 30 DAT                     | 60 DAT | 90 DAT |
| T <sub>0</sub>   | Control                      | 9.87              | 21.03  | 36.77  | 5.10                       | 10.13  | 18.47  |
| T <sub>1</sub>   | PSB 50L + Biochar 20t        | 13.60             | 24.87  | 39.89  | 5.87                       | 10.47  | 19.93  |
| T <sub>2</sub>   | PSB 100L/ha + Biochar 30t/ha | 21.20             | 41.73  | 65.83  | 7.80                       | 23.73  | 32.47  |
| T <sub>3</sub>   | PSB 150L/ha + Biochar 50t/ha | 16.27             | 40.80  | 62.30  | 6.80                       | 22.07  | 29.87  |
| T <sub>4</sub>   | PSB 50L/ha + Biochar 30t/ha  | 15.53             | 36.37  | 56.62  | 6.17                       | 18.97  | 29.87  |
| T <sub>5</sub>   | PSB 100L/ha + Biochar 50t/ha | 14.40             | 35.83  | 55.81  | 6.13                       | 17.87  | 29.80  |
| T <sub>6</sub>   | PSB 150L/ha + Biochar 20t/ha | 14.17             | 35.57  | 51.69  | 6.07                       | 15.90  | 28.87  |
| T <sub>7</sub>   | PSB 50L/ha + Biochar 50t/ha  | 13.95             | 35.20  | 49.65  | 6.00                       | 15.40  | 25.33  |

|                      |                              |       |       |       |      |       |       |
|----------------------|------------------------------|-------|-------|-------|------|-------|-------|
| T <sub>8</sub>       | PSB 100L/ha + Biochar 20t/ha | 17.63 | 40.87 | 63.75 | 7.00 | 22.53 | 31.13 |
| T <sub>9</sub>       | PSB 150L/ha + Biochar 30t/ha | 19.10 | 41.63 | 65.25 | 7.20 | 23.53 | 31.40 |
| F-test               |                              | S     | S     | S     | S    | S     | S     |
| S.E <sub>d</sub> (±) |                              | 1.72  | 2.38  | 1.75  | 0.47 | 1.10  | 2.28  |
| C.D at 5%            |                              | 3.62  | 4.99  | 3.68  | 0.99 | 2.31  | 4.80  |

**Table 1.1:** Influence of photosynthetic bacteria and biochar on growth parameters of broccoli.

| Treatment symbol     | Treatment combination        | Leaf area (CM SQ) |        |        | Leaf width (CM) |       |       |
|----------------------|------------------------------|-------------------|--------|--------|-----------------|-------|-------|
|                      |                              | 30 DAT            | 60DAT  | 90DAT  | 30 DAT          | 60DAT | 90DAT |
| T <sub>0</sub>       | Control                      | 115.40            | 242.59 | 316.08 | 4.43            | 6.59  | 13.82 |
| T <sub>1</sub>       | PSB 50L + Biochar 20t        | 124.05            | 281.11 | 384.56 | 5.53            | 8.00  | 14.73 |
| T <sub>2</sub>       | PSB 100L/ha + Biochar 30t/ha | 154.64            | 391.29 | 588.09 | 7.43            | 15.53 | 20.42 |
| T <sub>3</sub>       | PSB 150L/ha + Biochar 50t/ha | 147.85            | 374.66 | 575.12 | 6.38            | 11.25 | 17.68 |
| T <sub>4</sub>       | PSB 50L/ha + Biochar 30t/ha  | 138.57            | 344.55 | 487.29 | 6.37            | 10.87 | 17.55 |
| T <sub>5</sub>       | PSB 100L/ha + Biochar 50t/ha | 135.92            | 339.64 | 469.25 | 6.07            | 10.55 | 15.37 |
| T <sub>6</sub>       | PSB 150L/ha + Biochar 20t/ha | 131.49            | 313.69 | 461.88 | 5.77            | 9.83  | 15.21 |
| T <sub>7</sub>       | PSB 50L/ha + Biochar 50t/ha  | 129.25            | 291.25 | 440.22 | 5.63            | 9.10  | 14.37 |
| T <sub>8</sub>       | PSB 100L/ha + Biochar 20t/ha | 149.79            | 380.66 | 585.90 | 6.40            | 11.61 | 19.04 |
| T <sub>9</sub>       | PSB 150L/ha + Biochar 30t/ha | 150.79            | 382.64 | 586.65 | 6.83            | 12.13 | 19.73 |
| F-test               |                              | S                 | S      | S      | S               | S     | S     |
| S.E <sub>d</sub> (±) |                              | 4.52              | 37.16  | 27.11  | 0.41            | 1.40  | 0.48  |
| C.D at 5%            |                              | 9.50              | 78.07  | 56.96  | 0.85            | 2.95  | 1.01  |

**Table 1.2:** Influence of photosynthetic bacteria and biochar on growth parameters of broccoli.

| Treatment symbol     | Treatment combination        | Fresh weight of plant (g) | Fresh root weight (g) | Dry weight of plant (g) | Dry root weight (g) | Curd initiation(days) |
|----------------------|------------------------------|---------------------------|-----------------------|-------------------------|---------------------|-----------------------|
| T <sub>0</sub>       | Control                      | 410.51                    | 47.26                 | 45.13                   | 11.04               | 89.53                 |
| T <sub>1</sub>       | PSB 50L + Biochar 20t        | 466.55                    | 50.74                 | 59.76                   | 12.65               | 86.20                 |
| T <sub>2</sub>       | PSB 100L/ha + Biochar 30t/ha | 995.75                    | 105.50                | 193.60                  | 39.47               | 71.07                 |
| T <sub>3</sub>       | PSB 150L/ha + Biochar 50t/ha | 887.66                    | 96.56                 | 165.23                  | 31.71               | 73.30                 |
| T <sub>4</sub>       | PSB 50L/ha + Biochar 30t/ha  | 767.16                    | 81.6                  | 128.38                  | 23.04               | 79.20                 |
| T <sub>5</sub>       | PSB 100L/ha + Biochar 50t/ha | 693.80                    | 73.44                 | 117.48                  | 22.57               | 78.00                 |
| T <sub>6</sub>       | PSB 150L/ha + Biochar 20t/ha | 672.40                    | 70.78                 | 101.06                  | 20.69               | 77.67                 |
| T <sub>7</sub>       | PSB 50L/ha + Biochar 50t/ha  | 590.73                    | 69.19                 | 95.26                   | 14.68               | 77.27                 |
| T <sub>8</sub>       | PSB 100L/ha + Biochar 20t/ha | 923.34                    | 99.53                 | 179.82                  | 32.13               | 72.27                 |
| T <sub>9</sub>       | PSB 150L/ha + Biochar 30t/ha | 943.02                    | 99.77                 | 189.21                  | 35.20               | 71.53                 |
| F-test               |                              | S                         | S                     | S                       | S                   | S                     |
| S.E <sub>d</sub> (±) |                              | 49.65                     | 2.51                  | 1.54                    | 1.26                | 0.84                  |
| C.D at 5%            |                              | 104.31                    | 5.27                  | 3.23                    | 2.66                | 1.76                  |

**Table 2:** Influence of photosynthetic bacteria and biochar on yield parameters of broccoli.

| Treatment symbol     | Treatment combination        | Head yield per plot (kg) | Head weight (g) | Head diameter (cm) | Head yield (t/ha) |
|----------------------|------------------------------|--------------------------|-----------------|--------------------|-------------------|
| T <sub>0</sub>       | Control                      | 1.76                     | 195.74          | 12.82              | 5.87              |
| T <sub>1</sub>       | PSB 50L + Biochar 20t        | 2.12                     | 235.71          | 12.95              | 7.07              |
| T <sub>2</sub>       | PSB 100L/ha + Biochar 30t/ha | 4.49                     | 499.37          | 16.55              | 14.98             |
| T <sub>3</sub>       | PSB 150L/ha + Biochar 50t/ha | 3.09                     | 343.63          | 16.01              | 10.30             |
| T <sub>4</sub>       | PSB 50L/ha + Biochar 30t/ha  | 2.97                     | 299.65          | 15.80              | 9.90              |
| T <sub>5</sub>       | PSB 100L/ha + Biochar 50t/ha | 2.81                     | 293.18          | 15.40              | 9.39              |
| T <sub>6</sub>       | PSB 150L/ha + Biochar 20t/ha | 2.69                     | 330.07          | 15.20              | 8.98              |
| T <sub>7</sub>       | PSB 50L/ha + Biochar 50t/ha  | 2.63                     | 313.18          | 14.96              | 8.79              |
| T <sub>8</sub>       | PSB 100L/ha + Biochar 20t/ha | 3.22                     | 358.03          | 16.09              | 10.73             |
| T <sub>9</sub>       | PSB 150L/ha + Biochar 30t/ha | 4.22                     | 468.82          | 16.13              | 14.06             |
| F-test               |                              | S                        | S               | S                  | S                 |
| S.E <sub>d</sub> (±) |                              | 0.09                     | 9.75            | 0.18               | 0.29              |
| C.D at 5%            |                              | 0.18                     | 20.48           | 0.38               | 0.61              |

**Table 3:** Influence of photosynthetic bacteria and biochar on biochemical parameters of broccoli.

| Treatment symbol | Treatment combination        | Chlorophyll 'a'(mg/g/Fr.wt.) | Chlorophyll 'b'(mg/g/Fr.wt.) | Total chlorophyll (mg/g/Fr.wt.) | Leaf proline content (µg/g FW) | Vitamin C (mg/100g broccoli fresh head) |
|------------------|------------------------------|------------------------------|------------------------------|---------------------------------|--------------------------------|---|
| T <sub>0</sub>   | Control                      | 1.07                         | 0.67                         | 1.75                            | 0.14                           | 79.95                                   |
| T <sub>1</sub>   | PSB 50L + Biochar 20t        | 1.15                         | 0.73                         | 1.97                            | 0.08                           | 80.56                                   |
| T <sub>2</sub>   | PSB 100L/ha + Biochar 30t/ha | 1.74                         | 1.59                         | 3.59                            | 0.01                           | 91.55                                   |
| T <sub>3</sub>   | PSB 150L/ha + Biochar 50t/ha | 1.49                         | 1.41                         | 3.22                            | 0.03                           | 85.4                                    |
| T <sub>4</sub>   | PSB 50L/ha + Biochar 30t/ha  | 1.38                         | 1.29                         | 2.19                            | 0.03                           | 81.57                                   |
| T <sub>5</sub>   | PSB 100L/ha + Biochar 50t/ha | 1.27                         | 1.22                         | 2.17                            | 0.04                           | 81.19                                   |
| T <sub>6</sub>   | PSB 150L/ha + Biochar 20t/ha | 1.27                         | 1.10                         | 2.13                            | 0.04                           | 80.94                                   |
| T <sub>7</sub>   | PSB 50L/ha + Biochar 50t/ha  | 1.26                         | 0.99                         | 2.13                            | 0.05                           | 80.57                                   |

|                |                              |      |      |      |      |       |
|----------------|------------------------------|------|------|------|------|-------|
| T <sub>8</sub> | PSB 100L/ha + Biochar 20t/ha | 1.51 | 1.42 | 3.30 | 0.02 | 83.56 |
| T <sub>9</sub> | PSB 150L/ha + Biochar 30t/ha | 1.52 | 1.46 | 3.35 | 0.02 | 83.62 |
| F-test         |                              | S    | S    | S    | S    | S     |
| S.Ed (±)       |                              | 0.02 | 0.06 | 0.06 | 0.01 | 1.92  |
| C.D at 5%      |                              | 0.05 | 0.12 | 0.13 | 0.01 | 4.02  |

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