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# Effect of different organic manures and bio-fertilizers on economics and yield of red cabbage (*Brassica oleracea* L. var. *capitata* f. *rubra*)

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## Abstract
Red cabbage (*Brassica oleracea* L. var. *capitata* f. *rubra*) is a nutritionally rich, high-value cruciferous vegetable known for its vibrant anthocyanin pigmentation and health-promoting properties. Despite its market potential, red cabbage cultivation in India remains limited and often underexploited, with average yields of 3035 t/ha. However, integrated nutrient management practices incorporating organic manures and bio-fertilizers have shown promise in enhancing yield and profitability. This study was conducted at Mata Gujri College, Fatehgarh Sahib (Punjab), to evaluate the effect of different organic manures (FYM, poultry manure, vermicompost) and bio-fertilizers (Azotobacter, PSB, KSB) on the yield and economics of red cabbage under a factorial randomized block design with 16 treatments and 3 replications. Results revealed that the treatment combining *Azotobacter* @ 5 kg $ha^{-1}$ with vermicompost @ 5 t $ha^{-1}$ recorded the highest gross return (₹765,173.33 $ha^{-1}$), net return (₹647,803.08 $ha^{-1}$) and one of the highest yields. The highest benefit: cost ratio (6.00:1) was observed with *Azotobacter* + poultry manure. Phosphate Solubilizing Bacteria (PSB) enhanced phosphorus availability through solubilization of soil phosphates, promoting root development and head formation, while Potash Solubilizing Bacteria (KSB) improved potassium availability, crucial for head compactness and quality. Treatments involving PSB and KSB in combination with vermicompost or poultry manure also yielded significantly better results than control.

**Keywords:** Azotobacter, vermicompost, potash solubilizing bacteria (KSB), red cabbage

## Introduction
Red cabbage is botanically known as *Brassica oleracea* L. *var. capitata f. rubra*, belonging to the Brassicaceae family (Kachari M, 2012) [11]. It is a cultivar of the same species that includes green cabbage, cauliflower, broccoli, kale, Brussels sprouts, etc. The red-pigmented heads confer high levels of anthocyanins and vitamin C, making it nutritionally and commercially valuable (Manasa S, 2017) [1]. In India, cabbage (including red cabbage) productivity has been improving gradually under both inorganic and integrated nutrient management. Typical head yields for cabbage vary regionally from 250 to 450 quintals per hectare (~2545 t/ha) under conventional farming. For example, studies in Jaunpur, Uttar Pradesh, reported a peak head yield of ~687 q/ha (≈ 68.7 t/ha) when vermicompost combined with Azotobacter + PSB was used. Another trial at Prayagraj (UP) found that farmyard manure at 20 t/ha plus bio-fertilizers achieved 71.60 t/ha yield, with a B:C ratio of 4.52 (Chaudhary M M, 2018) [10]. Though these studies involved green cabbage, red cabbage is expected to respond similarly, since it belongs to the same species and shares similar nutrient uptake patterns (Lodhi P, 2017) [12]. Currently, national average yields are lower around 3035 t/ha, but researchers have achieved up to 70 t/ha under well-managed organic + biofertilizer regimes. Red cabbage remains a niche high-value crop in Indian Horticultural markets (Mebrahtu M, 2018) [2].

Organic manures such as farmyard manure (FYM), vermicompost, poultry manure, pressmud, neem cake etc. supply macronutrients (N, P, K) and improve soil structure, water retention and microbial activity. Bio-fertilizers, including Azotobacter (nitrogen-fixing), Phosphate-Solubilizing Bacteria (PSB) and Potash-Solubilizing Bacteria (KSB), enhance nutrient availability by converting fixed soil phosphorus and potassium into soluble forms, as well as synthesizing phytohormones and vitamins to stimulate root growth and yield efficiency (Lallawmkima, Singh S K, 2018) [3]. PSB play a key role in increasing phosphorus availability by solubilizing insoluble phosphates in the soil through secretion of organic acids and enzymes. Enhanced P availability promotes root development, head formation and improved quality of cabbage heads (Tyagi M K, 2003) [4]. Numerous field trials across horticultural crops (e.g., banana, brinjal, strawberry) have demonstrated yield improvements when PSB is used along with chemical P or organic manures. In cabbage specifically, inoculation with PSB, often combined with Azotobacter and partial inorganic P, improved head yield, TSS and vitamin C in cabbage studies in HP and other states (Bhardwaj A K, 2007) [5]. KSB release potassium locked in soil minerals or organic forms, making it available to plants. Potassium is crucial for cabbage head compactness, TSS levels and stress tolerance. While fewer studies focus on KSB for cabbage, Azotobacter + PSB + KSB combinations have been widely recommended as bio-fertilizer consortiums for vegetables. In early trials on cauliflower and cabbage, inclusion of KSB together with PSB and Azotobacter improved yield and quality better than single-inoculants.

## Materials and Methods

The current experiment was carried out at Experimental Research Farm of Department of Agriculture, Mata Gujri College, Fatehgarh Sahib. Fatehgarh Sahib town located on Ambala-Ludhiana national highway no. 1 and is well connected through road linkage to other important town cities of Punjab as well Union Territories Chandigarh which is capital of Punjab. Fatehgarh Sahib is 50 km away from Chandigarh and 35 km from Patiala. The town lies between at 76°-22'E to 76°-46'E latitude and 30°-36'N to 30°-39'N longitude and at a mean height of 279 m above sea level. The experiment was laid out in factorial randomized block design (FRBD). The total number of treatments is sixteen with three replications. Total number of plots were 48 and total net cultivates area was 278.25 $m^2$ with seed rate at 500 g $ha^{-1}$.

**Table 1:** Details of Treatments

| Treatment | Treatment Combination (Bio-fertilizer and Organic manure) |
|---|---|
| $T_1$ | Control |
| $T_2$ | No Bio-fertilizer + FYM @ 20.0 t $ha^{-1}$ |
| $T_3$ | No Bio-fertilizer + Poultry Manure @ 10 t $ha^{-1}$ |
| $T_4$ | No Bio-fertilizer + Vermicompost @ 5 t $ha^{-1}$ |
| $T_5$ | *Azotobacter* @ 5.0 kg $ha^{-1}$ + No Manure |
| $T_6$ | *Azotobacter* @ 5.0 kg $ha^{-1}$ + FYM @ 20.0 t $ha^{-1}$ |
| $T_7$ | *Azotobacter* @ 5.0 kg $ha^{-1}$ + Poultry Manure @ 10 t $ha^{-1}$ |
| $T_8$ | *Azotobacter* @ 5.0 kg $ha^{-1}$ + Vermicompost @ 5 t $ha^{-1}$ |
| $T_9$ | PSB @ 5.0 kg $ha^{-1}$ + No Manure |
| $T_{10}$ | PSB @ 5.0 kg $ha^{-1}$ + FYM @ 20.0 t $ha^{-1}$ |
| $T_{11}$ | PSB @ 5.0 kg $ha^{-1}$ + Poultry Manure @ 10 t $ha^{-1}$ |
| $T_{12}$ | PSB @ 5.0 kg $ha^{-1}$ + Vermicompost @ 5 t $ha^{-1}$ |
| $T_{13}$ | KSB @ 5.0 kg $ha^{-1}$ + No Manure |
| $T_{14}$ | KSB @ 5.0 kg $ha^{-1}$ + FYM @ 20.0 t $ha^{-1}$ |
| $T_{15}$ | KSB @ 5.0 kg $ha^{-1}$ + Poultry Manure @ 10 t $ha^{-1}$ |
| $T_{16}$ | KSB @ 5.0 kg $ha^{-1}$ + Vermicompost @ 5 t $ha^{-1}$ |

*PSB = Phoshphate solubilizing bacteria
*KSB = Potash solubilizing bacteria

### Cabbage Head yield q $ha^{-1}$

Total yield of head per plot was recorded by weighing the head from each plot separately. On the basis of yield obtained from per plot in kilogram. Head yield per hectare was calculated on the basis of per plot yield and expressed in quintals.

### Cost of Cultivation (₹ $ha^{-1}$)

The total cost of cultivation from sowing to marketing includes the total opportunity cost of each factor of production as part of its fixed or variable cost.

Cost of cultivation (₹ $ha^{-1}$) = Total common cost + Total variable cost

### Gross income (₹ $ha^{-1}$)

The gross monetary returns or total revenue was worked out by considering the yield from different treatments and the prevailing market price of the produce.

Gross Income (₹ $ha^{-1}$) = Total yield (kg $ha^{-1}$) x Selling price of produce

### Net return (₹ $ha^{-1}$)

The net return was measured by subtracting the cost of cultivation from the gross income.

Net return (₹ $ha^{-1}$) = Gross income-Cost of cultivation

### Benefit: Cost ratio (B: C ratio)

Benefit: cost ratio for different treatment was worked out by dividing the net return obtained from the respective treatment with respective total cost of cultivation.

## Results and Discussion

### Cabbage Head yield q $ha^{-1}$

Effect of organic manure and bio-fertilizer on cabbage head yield $ha^{-1}$ was significant and maximum head yield (559.75 q $ha^{-1}$) was found in treatment *Azotobacter* @ 5.0 kg $ha^{-1}$ which was at par with treatments PSB @ 5.0 kg $ha^{-1}$ i.e. 538.95 q $ha^{-1}$. Whereas, the minimum head yield (337.15 q $ha^{-1}$) was recorded in the treatment control. In organic manure application the maximum head yield at 545.90 q $ha^{-1}$ was recorded in treatment Vermicompost @ 5 t $ha^{-1}$, which was statistically at par with treatments Poultry manure @ 10 t $ha^{-1}$ i.e. 529.70 q $ha^{-1}$. Whereas, the minimum head yield at 358.66 q $ha^{-1}$ was observed in the control treatment. Among the interaction significantly maximum head yield 637.64 q $ha^{-1}$ was found in *Azotobacter* @ 5.0 kg $ha^{-1}$ + Vermicompost @ 5 t $ha^{-1}$, which was significantly at par with PSB @ 5.0 kg $ha^{-1}$ + Vermicompost @ 5 t $ha^{-1}$ i.e. 629.10 q $ha^{-1}$, *Azotobacter* @ 5.0 kg $ha^{-1}$ + Poultry Manure @ 10 t $ha^{-1}$ i.e. 626.28 q $ha^{-1}$ and the minimum head yield (176.30 q $ha^{-1}$) was observed in Control. This is due to the improvement in yield characters of the crop with the application *Azotobacter* may be due to its ability to fixing nitrogen and make readily available to plants. Increase in the total yield due to *Azotobacter* inoculation has also been reported by Tyagi *et al.* (2003) [4], Bahadur *et al.* (2006) [13]. The increased head yield $ha^{-1}$ under vermicompost manure may be due to decreased soil temperature and more efficient conservation of water which favoured growth of the crop (Kabir *et al.*, 2016) [14] and Jamil *et al.* (2005) [15] also observed similar results.

**Cost of cultivation (₹ ha$^{-1}$)**

The data pertaining to the economics of production for different treatments have been depicted in Table 2. Examination of the data revealed that minimum cost of cultivation ₹ 87055.00 was observed in Control followed by *Azotobacter* @ 5.0 kg ha$^{-1}$ + No manure at ₹ 87370.25 and PSB @ 5.0 kg ha$^{-1}$ + No manure at ₹ 87375.40 whereas maximum cost of cultivation ₹ 117680.00 was observed in KSB @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$.

**Gross return (₹ ha$^{-1}$)**

The data pertaining to the economics of production for different treatments have been depicted in Table 2. Examination of the data revealed that maximum gross return ₹ 765173.33 was observed in *Azotobacter* @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ followed by PSB @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ at ₹ 754915.55 and PSB @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ at ₹ 703715.55 whereas minimum gross return ₹ 325440.00 was observed in Control treatment. It is clear with our findings the maximum return with vermicompost might be due to highest yield of green pod per ha. It is possible due to the application of organic manure and inorganic fertilizer due to that the availability of nutrients is in increased and total production was also increased so that the gross return was increased. This finding was also highly correlated to the findings of Firoz (2009) [7] and Sharma *et al.* (2009) [8].

**Net return (₹ ha$^{-1}$)**

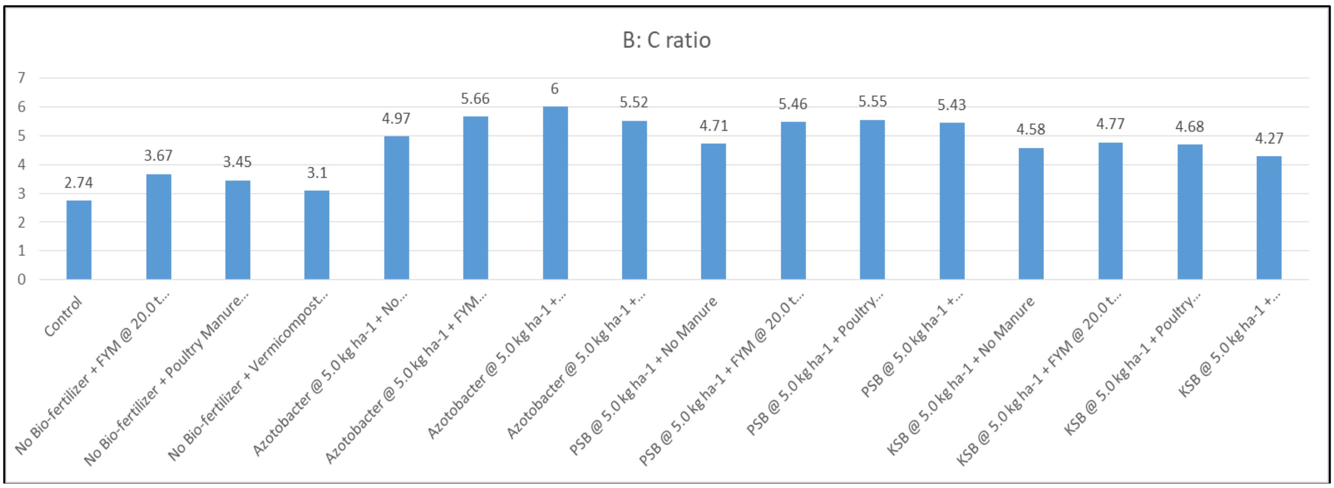
The data pertaining to the economics of production for different treatments have been depicted in Table 2. Examination of the data revealed that maximum net return ₹ 647803.08 was observed in *Azotobacter* @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ followed by *Azotobacter* @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ at ₹ 644167.53 and PSB @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ at ₹ 637540.15 whereas minimum net return ₹ 238385.00 was observed in Control treated plots.

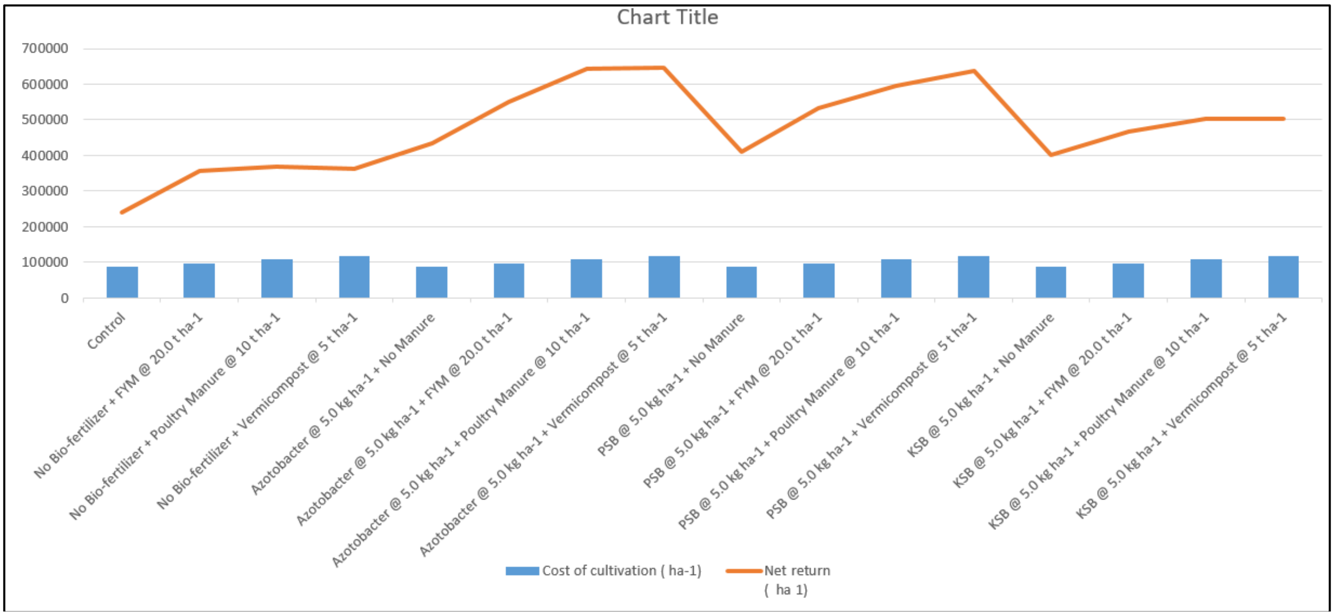
**Benefit cost ratio**

The data pertaining to the economics of production for different treatments have been depicted in Table 2. Examination of the data revealed that maximum benefit cost ratio 6.00:1 was observed in *Azotobacter* @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ followed by *Azotobacter* @ 5.0 kg ha$^{-1}$ + FYM @ 20 t ha$^{-1}$ having benefit cost ratio 5.66:1 and PSB @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ benefit cost ratio at 5.55:1. Whereas, minimum benefit cost ratio 2.74:1 was observed in Control plots. It is possible due to the application of organic manure and bio-fertilizer due to that the availability of nutrients is in increased and total production was also increased so that the gross return was increased. This finding was also highly correlated to the findings of Firoz (2009) [7] and Sharma *et al.* (2009) [8] in knolkhol.

**Table 2:** Effect of different organic manures and biofertilizers on economics and yields of red cabbage.

| Treatment combination | Cabbage Head yield q ha$^{-1}$ | Cost of cultivation (₹ ha$^{-1}$) | Gross return (₹ ha$^{-1}$) | Net return (₹ ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|
| Control | 176.30 | 87055.00 | 325440.00 | 238385.00 | 2.74 |
| No Bio-fertilizer + FYM @ 20.0 t ha$^{-1}$ | 378.00 | 97055.00 | 453600.00 | 356545.00 | 3.67 |
| No Bio-fertilizer + Poultry Manure @ 10 t ha$^{-1}$ | 396.59 | 107055.00 | 475911.11 | 368856.11 | 3.45 |
| No Bio-fertilizer + Vermicompost @ 5 t ha$^{-1}$ | 399.70 | 117055.00 | 479644.44 | 362589.44 | 3.10 |
| *Azotobacter* @ 5.0 kg ha$^{-1}$ + No Manure | 434.83 | 87370.25 | 521795.56 | 434425.31 | 4.97 |
| *Azotobacter* @ 5.0 kg ha$^{-1}$ + FYM @ 20.0 t ha$^{-1}$ | 540.25 | 97370.25 | 648302.22 | 550931.97 | 5.66 |
| *Azotobacter* @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ | 626.28 | 107370.25 | 751537.78 | 644167.53 | 6.00 |
| *Azotobacter* @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ | 637.64 | 117370.25 | 765173.33 | 647803.08 | 5.52 |
| PSB @ 5.0 kg ha$^{-1}$ + No Manure | 415.94 | 87375.40 | 499128.89 | 411753.49 | 4.71 |
| PSB @ 5.0 kg ha$^{-1}$ + FYM @ 20.0 t ha$^{-1}$ | 524.34 | 97375.40 | 629208.89 | 531833.49 | 5.46 |
| PSB @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ | 586.43 | 107375.40 | 703715.55 | 596340.15 | 5.55 |
| PSB @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ | 629.10 | 117375.40 | 754915.55 | 637540.15 | 5.43 |
| KSB @ 5.0 kg ha$^{-1}$ + No Manure | 407.56 | 87680.00 | 489066.67 | 401386.67 | 4.58 |
| KSB @ 5.0 kg ha$^{-1}$ + FYM @ 20.0 t ha$^{-1}$ | 469.36 | 97680.00 | 563235.55 | 465555.55 | 4.77 |
| KSB @ 5.0 kg ha$^{-1}$ + Poultry Manure @ 10 t ha$^{-1}$ | 509.50 | 107680.00 | 611395.55 | 503715.55 | 4.68 |
| KSB @ 5.0 kg ha$^{-1}$ + Vermicompost @ 5 t ha$^{-1}$ | 517.17 | 117680.00 | 620604.44 | 502924.44 | 4.27 |






## Conclusion

The present investigation highlights the beneficial impact of integrating organic manures and bio-fertilizers on the yield and economic viability of red cabbage (*Brassica oleracea* L. var. *capitata* f. *rubra*). Among all treatments, the combination of *Azotobacter* @ 5.0 kg ha⁻¹ with vermicompost @ 5 t ha⁻¹ produced the highest gross return (₹765,173.33 ha⁻¹) and net return (₹647,803.08 ha⁻¹), while *Azotobacter* with poultry manure achieved the highest benefit:cost ratio of 6.00:1. These results indicate that organic and biological inputs can significantly improve nutrient availability, enhance soil fertility and promote better plant growth and head development compared to control or chemical-only approaches. Phosphate Solubilizing Bacteria (PSB) and Potash Solubilizing Bacteria (KSB) played crucial roles in increasing phosphorus and potassium availability, respectively, contributing to improved yield attributes such as head weight, compactness and total soluble solids. The integration of bio-fertilizers with organic amendments such as vermicompost and poultry manure not only reduced dependency on chemical fertilizers but also promoted sustainable soil health. Therefore, it can be concluded that the integrated use of *Azotobacter*, PSB and KSB with organic manures is an eco-friendly and economically viable strategy to enhance red cabbage productivity and profitability, especially in regions adopting sustainable horticultural practices.

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