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Studies on effect of organic and inorganic fertilizers on growth, yield attributes of cabbage (*Brassica oleracea* L. var. Capitata)

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Abstract
The present research entitled "Studies on effect of organic and inorganic fertilizers on growth, yield attributes of cabbage (*Brassica oleracea* L. var. capitata)" was carried out at the research block of the Medicinal and Aromatic Plant Research Station, Rajendranagar, during *Rabi*-2020. The experiment was laid in factorial randomized block design with three replications.
The experiment was executed with objectives to study the effect of organic fertilizers on growth and yield of cabbage, to study the effect of inorganic fertilizers on growth and yield of cabbage, to study the effect of organic and inorganic fertilizers on growth and yield of cabbage.
Among the organic fertilizers [vermicompost (5 t/ha), *Azotobacter* (4 kg/ha), *Azospirillum* (4 kg/ha), *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha)] in cabbage. *Azotobacter* (4 kg/ha) +*Azospirillum* (4 kg/ha) significantly recorded the maximum polar diameter of cabbage (15.16 cm), equatorial diameter of cabbage (11.77 cm), head yield per plot (19.86 kg) and head yield per hectare (331.12 q).
Among the different levels of inorganic fertilizers [100% RDF, 75% RDF, 50% RDF] in cabbage. 100% RDF through inorganic fertilizers significantly recorded the maximum polar diameter of cabbage (15.59 cm), equatorial diameter of cabbage (12.12 cm), head yield per plot (19.15 kg), head yield per hectare (319.21q). 100% RDF through inorganic nutrients treated plant also took minimum number of days to first leaf folding (30.64), days to 50% head maturity (80.09).
The interaction between organic fertilizers and inorganic fertilizers has shown significant results, the maximum polar diameter of cabbage (16.12 cm), equatorial diameter of cabbage (12.37 cm), head yield per plot (22.36 kg), head yield per hectare (372.77 q) was noticed in *Azotobacter* + *Azospirillum* in combination with 100% RDF. Highest benefit cost ratio (3.72) was recorded at (T_8) - *Azotobacter* + *Azospirillum* in combination with 75% RDF which was followed by (T_4) - *Azotobacter* + *Azospirillum* in combination with 100% RDF (3.67) and lowest benefit cost ratio was recorded in (T_9) - vermicompost (5 t/ha) in combination with 50% RDF through inorganic fertilizers.
From the above results, it can be concluded that highest plant growth and yield in cabbage recorded in application of *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha) with 100% RDF through inorganic fertilizers followed by application of *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha) with 75% RDF through inorganic fertilizers and lowest plant growth, yield is recorded in application vermicompost (5 t/ha) with 50% RDF through inorganic fertilizers. Whereas highest benefit cost ratio is recorded in plots with application of *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha) with 75% RDF through inorganic fertilizers.

Keywords: Cabbage, vermicompost, Azotobacter, Azospirillum

Introduction
Cabbage (*Brassica oleracea* L. *var. capitata*) belongs to the cole group of vegetables which belongs to the family brassicaceae and originated from a single wild ancestor *Brassica oleracea L. var. oleracea* (*Syn. sylvestris*) commonly known as wild cabbage, cliff cabbage or 'Colewarts'
India is the second largest producer of cabbage in the world, next to China, accounting for 16.55 per cent of the world area and 12.79 per cent of the world production. In India, it is grown in an area of 4.00 lakh hectare with an annual production of 9.03 million tonnes and productivity of 22.6 t/ha, ranking second to cauliflower in area but topping in production among cole crops. In Telangana, cabbage is grown in an area of 2.34 thousand hectares with production of 49.12 thousand tonnes.
In the past century, world food production increased dramatically due to enhanced crop yields as a result of widespread adoption of technologies such as mechanization, new high-yielding and disease resistant crop varieties, irrigation and especially the use of mineral fertilizers.

While crop yields were the primary focus in the past, awareness of increasing population growth and limited potential to bring more land into production led to the notion of cropping sustainability or sustainable intensification, i.e. consistently achieving high crop yields without damaging the soil's capacity to produce such yields. Thus, the current focus in soil and crop management is on maintenance of soil quality or soil health.

Materials and Methods

The experiment was laid out in Factorial Randomized block design with three replications and twelve treatments *viz*., T_1- Vermicompost (5 t ha^{-1}) + 100% RDF, T_2- *Azotobacter* (4 kg ha^{-1}) 100% RDF, T_3- *Azospirillum* (4 kg ha^{-1}) + 100% RDF, T_4- *Azotobacter* (4 kg ha^{-1}) + *Azospirillum* (4 kg ha^{-1}) +100% RDF, T_5 - Vermicompost (5t $ha^{-1)}$ +75% RDF, T_6- *Azotobacter* (4 kg ha^{-1}) + 75% RDF, T_7 - *Azospirillum* (4 kg ha^{-1}) + 75% RDF, T_8- *Azotobacter* (4 kg ha^{-1}) + *Azospirillum* (4 kg ha^{-1}) + 75% RDF, T_9- Vermicompost (5t ha^{-1}) + 50% RDF, T_{10}- *Azotobacter* (4kg ha^{-1}) + 50% RDF, T_{11}- *Azospirillum* (4 kg ha^{-1}) + 50% RDF, T_{12}- *Azotobacter* (4 kg ha^{-1}) + *Azospirillum* (4kg ha^{-1}) + 50% RDF.

Number of days to first leaf folding was recorded as number of days taken from date of transplanting to the first leaf folding. Number of days to 50% head maturity was recorded as number of days taken from date of transplanting to the date when marketable size heads of 50% plant in a plot/treatment were harvested. Polar diameter (cm) in centimetre was measured after cutting the head into 2 halves longitudinally. Equatorial diameter (cm) was measured after cutting the head into 2 halves transversally. Yield per plot (kg) was calculated by pooling the net head weight of all the heads in a plot. Yield per hectare (q) On the basis of yield obtained from per plot in kilogram, yield per hectare was calculated in quintals.

Results and Discussion

1. Days to first leaf folding

The data with respect to number of days to first leaf folding as influenced by organic and inorganic fertilizers with its interactions is presented in Table 1.

The treatment (B_4) *Azotobacter* + *Azospirillum* recorded minimum number of days to first leaf folding (30.94) which was followed by (B_3) *Azospirillum* (32.20) and (B_1) vermicompost (32.22). Maximum number of days to first leaf folding (33.02) was recorded with (B_2) *Azotobacter*.

Significantly minimum number of days to first leaf folding (30.64) was recorded with (A_1) 100% RDF followed by (A_2) 75% RDF (31.68). Maximum number of days to first leaf folding (33.96) was recorded with (A_3) 50% RDF.

The interaction between organic and inorganic fertilizers was significant with respect to days to first leaf folding. Significantly minimum number of days to first leaf folding (29.41) was recorded in (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum* which was statistically superior over other treatments. Maximum number of days to first leaf folding (35.44) was recorded in (A_3B_2) 50% RDF combination with *Azotobacter.*

From the data recorded regarding days required for first leaf folding, it was revealed that the treatment B_4 *(Azotobacter* + *Azospirillum*) showed significantly minimum number of days for first leaf folding over rest of the organic treatments. Treatment B_3 *(Azospirillum)* also recorded less days for head initiation. Similar results are obtained by Patil (2006) [14] in cabbage, Bhagavantagoudra and Rokhade (2001) [3] in cabbage.

Results with regard to days required for first leaf folding revealed that nitrogen has significant effect on early head initiation. Treatment A_1 receiving 100% RDF recorded less days for first leaf folding over rest of the inorganic treatments. Pande *et al.* (1984) [12] in experiment on nitrogen fertilizer on cauliflower variety, snowball 16 recorded highest early yields. Interaction between organic and inorganic fertilizer treatments was significant. By reviewing the data, it was concluded that treatment combination A_1B_4 (100% RDF combination with *Azotobacter* + *Azospirillum)* was found superior in early head initiation. The probable reason for early head initiation might be that the hormones which enhanced early head initiation might be secreted by *Azotobacter* and *Azospirillum.* These results are in close agreement with the findings of Ukey (1993), Bambal *et al.* (1998) [1] and Kalyani *et al.* (1996) [9] in cauliflower, Bankar (1997) [2] and Gurav (2002) [8] in cabbage.

2. Days taken for 50% head maturity

The data with respect to days taken for 50% head maturity as influenced by organic and inorganic fertilizers with its interactions is presented in table 1.

The treatment (B_4) *Azotobacter* and *Azospirillum* recorded minimum number of days taken for 50% head maturity (80.74) which was statistically on par with (B_2) *Azotobacter* (80.98). Maximum number of days taken for 50% head maturity (83.30) was recorded with (B_1) vermicompost.

Significantly minimum number of days taken for 50% head maturity (80.09) was recorded with (A_1) 100% RDF followed by (A_2) 75% RDF (81.86). Maximum number of days taken for 50% head maturity (83.36) was recorded with (A_3) 50% RDF.

The interaction between organic and inorganic fertilizers was significant with respect to days taken for 50% head maturity. Significantly minimum number of days taken for 50% head maturity (79.48) was recorded in (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum*. Maximum number of days taken for 50% head maturity (83.30) was recorded in (A_3B_1) 50% RDF combination with vermicompost.

3. Equatorial diameter (cm)

The data with respect to equatorial diameter as influenced by organic and inorganic fertilizers with its interactions is presented in Table 2.

The treatment (B_4*)* *Azotobacter* + *Azospirillum* recorded maximum equatorial diameter (11.77 cm). However, minimum equatorial diameter (11.16 cm) was recorded in (B_1) vermicompost.

Significant variation was recorded among inorganic fertilizers (100% RDF, 75% RDF and 50% RDF). However, the highest equatorial diameter (12.12 cm) was recorded with (A_1) 100% RDF. Minimum equatorial diameter (10.69 cm) was recorded with (A_3) 50% RDF.

The interaction between organic and inorganic fertilizers was significant with respect to equatorial diameter. Significantly maximum equatorial diameter (12.37 cm) was recorded in (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum*. Minimum equatorial diameter (10.40 cm) was recorded in (A_3B_1) 50% RDF combination with vermicompost.

4. Polar diameter (cm)
The data with respect to polar diameter as influenced by organic and inorganic fertilizers with its interactions is presented in Table 2.
The treatment (B_4) *Azotobacter* + *Azospirillum* recorded maximum polar diameter (15.16 cm). However, minimum polar diameter (14.52 cm) was recorded in (B_1) vermicompost.
Significant variation was recorded among inorganic fertilizers (100% RDF, 75% RDF and 50% RDF). However, the highest polar diameter (15.59 cm) was recorded with (A_1) 100% RDF. Minimum polar diameter (13.84 cm) was recorded with (A_3) 50% RDF.
The interaction between organic and inorganic fertilizers was significant with respect to polar diameter. Significantly maximum polar diameter (16.12 cm) was recorded in (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum*. Minimum polar diameter (13.79 cm) was recorded in (A_3B_2) 50% RDF combination with *Azotobacter* and (A_3B_4) 50% RDF combination with *Azospirillum* (13.79).

5. Yield per plot (kg)
The data pertaining to yield per plot as influenced by organic and inorganic fertilizers with its interactions is presented in Table 3.
For yield per plot significant difference among the organic fertilizer treatments was recorded. The treatment (B_4) *Azotobacter* + *Azospirillum* recorded highest yield per plot (19.86) which was statistically superior over rest of the treatments and followed by the treatment (B_3) *Azospirillum* (18.78). However, lowest yield per plot (15.66) was recorded in treatment (B_1) vermicompost.
There was significant variation recorded among inorganic fertilizers (100% RDF, 75% RDF and 50% RDF). However, highest yield per plot (19.15) was recorded with treatment (A_1) 100% RDF which was on par with treatment (A_2) 75% RDF (19.05). Lowest yield per plot (14.87) was recorded with treatment (A_3) 50% RDF.
The interaction of organic and inorganic fertilizers exhibited significant effect on yield per plot. However, highest yield per plot (22.36) was recorded in (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum* which was on par with (A_2B_4) 75% RDF combination with *Azotobacter* + *Azospirillum* (22.16). Lowest yield per plot (14.40) was recorded in (A_3B_2) 50% RDF combination with *Azotobacter.*

6. Yield per hectare (quintals)
The data pertaining to yield per hectare as influenced by organic and inorganic fertilizers with its interactions is presented in Table 3.
For yield per hectare there is a significant difference among the organic fertilizer treatments was recorded. The treatment (B_4) *Azotobacter* + *Azospirillum* recorded highest yield per hectare (331.12) lowest yield per hectare (260.99) was recorded in treatment (B_1) vermicompost.
There was significant variation recorded among inorganic fertilizers (100% RDF, 75% RDF and 50% RDF). However, highest yield per hectare (319.21) was recorded with treatment (A_1) 100% RDF which is on par with treatment (A_2) 75% RDF (317.63). Lowest yield per hectare (247.87) was recorded with (A_3) 50% RDF.
The interaction of organic and inorganic fertilizers exhibited significant effect on yield per hectare. However, highest yield per hectare (372.77) was recorded in treatment (A_1B_4) 100% RDF combination with *Azotobacter* + *Azospirillum* which was on par with treatment (A_2B_4) 75% RDF combination with *Azotobacter* + *Azospirillum* (369.33). Lowest yield per hectare (239.99) was recorded in treatment (A_3B_2) 50% RDF combination with *Azotobactor.*

Gross weight, net weight, harvesting index, yield per plot, yield per hectare are important yield parameters
The yield parameters depend upon various factors. Besides other factors, it depends upon nutritional status of soil. The soil influences the vegetative growth of the plant which in turn leads to the head yield of plant. The spectacular nutrient fixing properties and making them available to plants by biofertilizers have revolutionized the nutrient management approach. This experiment also established the role of biofertilizers in increasing yield. These results are in close agreement with the results obtained by Khandait (1996) [10] in cabbage, Chattoo *et al.* (1997) [6] in knol-khol, Bhagavantagoudra and Rokhade (2001) [3] in cabbage.
In present investigation, it was observed that there was linear response to the application of inorganic fertilizers. Maximum gross weight, net weight, yield per plot and yield per hectare was obtained by the application of 120 kg nitrogen (100% RDF). This might be due to higher dose of nitrogen which helped to induce more vegetative growth which in turn lead to increased head yield.
Parmar *et al.* (1999) [13] suggested that the yield increased with increase in the rate of N application and 200 kg N/ha gave significantly higher yield over 105 kg N/ha in cabbage. Nagaiah *et al.* (2000) observed that application of 150 kg N/ha significantly increased the yield in cabbage. The results obtained in the present studies are on similar line.
The best combination of organic and inorganic fertilizer that resulted in the highest and a corresponding high level of yield attributes was 100% RDF + *Azotobacter* + *Azospirillum.* The yield obtained in treatment combination A_1B_4 was 372.77 q/ha which was significantly on par with treatment combination of 75% RDF + *Azotobacter* + *Azospirillum* yield obtained in treatment was 369.33.
Biofertilizers are known to release the bioactive substances having similar effect that of growth regulators besides enhancement of nutrient absorption (Patel *et al*., 1998). The advantage on yields by following different combinations of treatments by the integrated use of organic manures, biofertilizers and chemical fertilizers have also been reported in various cole crops by different workers namely Bhardwaj *et al.* (2007) [4] and Ghuge *et al.* (2007) [7] in cabbage, Rai *et al*. (2013) [15] in cabbage, Kumar *et al*. (2013) [11] in broccoli, Chattarjee *et al*. (2014) in cabbage, Sharma *et al.* (2014) [16] in cauliflower-French bean-okra sequence and Shree *et al*. (2014) [17] in cauliflower.

Table 1: Effect of organic and inorganic fertilizers on days to first leaf folding, 50% head maturity and polar diameter of cabbage.

	Days to first leaf folding					Days to 50% head maturity				
	B1	**B2**	**B3**	**B4**	**Mean A**	**B1**	**B2**	**B3**	**B4**	**Mean A**
A1	31.36	31.11	30.68	29.41	30.64	80.25	80.12	80.51	79.48	80.09
A2	30.95	32.51	32.47	30.80	31.68	83.40	80.46	82.41	81.15	81.86
A3	34.34	35.44	33.44	32.62	33.96	86.26	82.37	83.23	81.58	83.36
Mean B	32.22	33.02	32.20	30.94		83.30	80.98	82.05	80.74	
Factors		SE (m)		C.D.		SE (m)			C.D.	
Factor (A)		0.112		0.332		0.105			0.311	
Factor (B)		0.130		0.383		0.122			0.359	
Factor (AXB)		0.225		0.664		0.211			0.622	

A1: 100% RDF B1: Vermicompost (5 tha^{-1})
A2: 75% RDF B2: Azotobacter (4 kgha^{-1})
A3: 50% RDF B3: Azospirillum (4 kgha^{-1})
B4: *Azotobacter* (4 kgha^{-1}) + Azospirillum (4 kgha^{-1})

Table 2: Effect of organic and inorganic fertilizers on equatorial diameter and polar diameter of cabbage.

	Equatorial diameter (cm)					Polar diameter (cm)				
	B1	**B2**	**B3**	**B4**	**Mean A**	**B1**	**B2**	**B3**	**B4**	**Mean A**
A1	11.97	12.01	12.02	12.37	12.12	15.09	15.46	15.68	16.12	15.59
A2	11.10	11.16	11.10	11.95	11.33	14.56	14.84	14.80	15.56	14.94
A3	10.40	10.54	10.80	11.00	10.69	13.90	13.79	13.86	13.79	13.84
Mean B	11.16	11.27	11.31	11.77		14.52	14.70	14.78	15.16	
Factors		SE (m)		C.D.		SE (m)			C.D.	
Factor (A)		0.043		0.126		0.062			0.182	
Factor (B)		0.049		0.145		0.071			0.211	
Factor (AXB)		0.085		0.252		0.124			0.365	

A1: 100% RDF B1: Vermicompost (5 tha^{-1})
A2: 75% RDF B2: *Azotobacter* (4 kgha^{-1})
A3: 50% RDF B3: *Azospirillum* (4 kgha^{-1})
B4: *Azotobacter* (4 kgha^{-1}) + *Azospirillum* (4 kgha^{-1})

Table 3: Effect of organic and inorganic fertilizers on yield per plot and yield per hectare of cabbage.

	Yield per plot (kg)					Yield per hectare (quintals)				
	B1	**B2**	**B3**	**B4**	**Mean A**	**B1**	**B2**	**B3**	**B4**	**Mean A**
A1	16.37	16.92	20.95	22.36	19.15	272.	281.9	349.2	372.7	319.21
A2	15.84	18.08	20.14	22.16	19.05	263.	301.44	335.7	369.3	317.63
A3	14.77	14.40	15.24	15.07	14.87	246.	239.9	254.1	251.2	247.87
Mean B	15.66	16.47	18.78	19.86		260.	274.4	313.0	331.1	
Factors		SE (m)		C.D.		SE (m)			C.D.	
Factor (A)		0.214		0.632		3.450			10.183	
Factor (B)		0.247		0.730		3.984			11.759	
Factor (AXB)		0.428		1.264		6.900			20.367	

A1: 100% RDF B1: Vermicompost (5 tha^{-1})
A2: 75% RDF B2: *Azotobacter* (4 kgha^{-1})
A3: 50% RDF B3: *Azospirillum* (4 kgha^{-1})
B4: *Azotobacter* (4 kgha^{-1}) + *Azospirillum* (4 kgha^{-1})

Conclusion

From the results, it can be concluded that organic fertilizers [vermicompost (5t/ha), *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha), *Azotobacter* (4 kg/ha) + *Azospirillum* (4 kg/ha)] and inorganic fertilizers (100% RDF, 75% RDF, 50% RDF) with its combination significantly improved the plant growth and yield parameters. *Azotobacter* + *Azospirillum* significantly improved polar diameter of head, equatorial diameter of head, head yield per plot, head yield per hectare and took least number of days to first leaf folding, days to 50% head maturity, vermicompost significantly improved available phosphorus, potash content of soil. *Azotobacter* + *Azospirillum* significantly improved available nitrogen content of soil.

Finally, to conclude application of *Azotobacter* + *Azospirillum* in combination with 75% RDF through inorganic nutrients can be recommended as suitable crop nutrient management practice in cabbage to get higher benefit cost ratio and to improve the Physico-chemical properties of soil.

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