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Effect of organic manures and biofertilizers on yield, dry matter partitioning and quality traits of cabbage (*Brassica oleracea* var. *capitata*)

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ABSTRACT

The objective of this study was to evaluate the effects of three different biofertilizers in combination with four different organic manures or with inorganic fertilizers on dry matter partitioning, yield and quality traits in cabbage. Results indicated that treatments comprising recommended fertilizers package coupled with seedling inoculation in any biofertilizer had relatively higher dry matter in leaves (head), higher number of non-wrapper leaves and head yield (40.81–41.88±1.07 tonnes/ha). Application of pressmud or vermicompost plus seedling inoculation in *Azospirillum* or PSM noticed head yield at par with conventional fertilization. The total carbohydrate content in head was significantly higher with use of organic manures and VAM or PSM. The maximum protein content was noticed with sole application of vermicompost (17.4%) or digested sludge (17.3%). Fibre content in head was improved remarkably with the use of organic manures and biofertilizers. The highest total carotenoid content in head was recorded with the use of FYM + PSM (0.445 mg/100 g). Significantly higher ascorbic acid content (vitamin C) in head was registered with the use of either FYM or pressmud along with PSM or VAM (14.25–15.48±0.33 mg/100 g).

Key words: Biofertilizers, Cabbage, Organic manures, Quality, Yield

Among cole crops, cabbage (*Brassica oleracea* var. *capitata*) is most popular in the world and has highest area and production. Cabbage is good source of protein with high biological value and digestibility. Its leaves are rich in vitamin A, B_1, B_2 and minerals and are an excellent source of vitamin C. Cabbage is also reported to have significant anti-cancer activity (Beecher 1994). The increased use of chemicals under intensive cultivation has disturbed the harmony existing among soil, plant and microbial population. As a result, the thrust since the last decade has been more towards sustainable farming practices for the conservation of natural resources, eco-friendly production technologies and integrated crop management practices. This has necessitated the identification of renewable inputs like organic manures, crop residues, soil microbes, etc. The use of organic manures in soil has been associated with desirable soil properties including soil fertility, water-holding capacity, high cation exchange capacity and low bulk density and can foster diverse population of beneficial soil microorganisms (Bulluck *et al*. 2002). Inoculation of crop with beneficial microorganisms can enhance the atmospheric nitrogen fixation, decompose organic wastes and residues, improve soil properties, enhance nutrients cycling and produce bioactive compounds, such as vitamins, hormones and enzymes that stimulate plant growth (Parr *et al*. 1994, Wu *et al*. 2005). There are some reports, which indicate that the combined application of organic manures and biofertilizers increased yield and improve quality of vegetables (Bahadur *et al.* 2006, 2009).

MATERIALS AND METHODS

A field experiment was carried out at Indian Institute of Vegetable Research, Varanasi during 2004 and 2005. The treatments comprised seedling inoculation in biofertilizer, viz vesicular-arbuscular mycorrhizae (VAM), phosphate-solubilizing microorganisms (PSM) and *Azospiriluum*, along with three organic manures or with recommended fertilizer package. Total 16 treatments [T_1, farmyard manure 20 tonnes/ ha + *Azospirillum*; T_2, farmyard manure 20 tonnes/ ha+ vesicular arbuscular-mycorrhiza (VAM); T_3, farmyard manure 20 tonnes/ ha + phosphate-solubilizing microorganism (PSM); T_4, digested sludge 20 tonnes/ ha + *Azospirillum*; T_5, digested

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sludge 20 tonnes/ ha + VAM; T_6, digested sludge 20 tonnes/ ha + PSM; T_7, pressmud 15 tonnes/ ha + *Azospirillum*; T_8, pressmud 15 tonnes/ ha + VAM; T_9, pressmud 15 tonnes/ ha + PSM; T_{10}, vermicompost 10 tonnes/ ha + *Azospirillum*; T_{11}, vermicompost 10 tonnes/ ha + VAM; T_{12}, vermicompost 10 tonnes/ ha + PSM; T_{13}, recommended NPK + *Azospirillum*; T_{14}, recommended NPK + VAM; T_{15}, Rec. NPK + PSM and T_{16}; recommended NPK (150:60:80 kg/ha) only] including control (N:P:K-150:60:80 kg/ ha) were replicated thrice in RBD arrangement.

The soil of experimental plot was sandy loam (Inceptisol), *p*H 7.6, EC 0.41 dS/ m, organic carbon 0.39%, available nitrogen 210.15 kg/ ha, phosphorus 18.24 kg/ ha and potassium 256.35 kg/ha. The roots of four weeks old seedlings of cabbage cv. Golden Acre were inoculated with biofertilizers, and transplanted at spacing 50cm×50 cm in 3×3 m^2 plots on 20 and 25 November in 2004 and 2005 respectively. Half dose of N and full of P and K were applied as basal during planting (T_{13} to T_{16}) and rest of N was top-dressed in two split doses at 30 and 60 days after transplanting (DAT).

The dry matter partitioning in various plant parts was estimated twice, at active growth stage (45 DAT) and at edible maturity (70 DAT). For biochemical analysis, samples of 10 g cabbage from each replicate were taken at 70 days after transplanting. The total carbohydrates were estimated as per procedure described by Krishnaveni *et al*. (1984). The protein content in head was estimated by Micro-Kjeldahl method. The total carotenoids were estimated according to the methods suggested by Jensen (1978). Ascorbic acid (vitamin C) content was estimated by AOAC's official titrimetric method (AOAC 1990). Crude fibre was determined using the Fibertec 2021 Fiber Cap™ system as per AOAC 962.09.

RESULTS AND DISCUSSION

Dry matter partitioning

An appropriate distribution of biomass in different plant parts is an important aspect, which ultimately determines the yield. In present investigation, the treatments comprising recommended fertilizers package coupled with seedling inoculation with any biofertilizer have proportionally translocated less dry matter in stems (7.5–7.8 and 2.0–2.5% at 45 and 70 DAT respectively) and roots (4.8–5.5 and 2.1–2.3% at 45 and 70 DAT, respectively) and relatively higher dry matter in leaves or heads (86.6–87.7 and 95.3–95.7% at 45 and 70 DAT respectively (Fig 1). The maximum biomass allocation in leaves was obviously due to more initial biomass synthesis in leaves, less biomass accumulation in stem and balanced biomass distribution in roots. Earlier, Bahadur *et al*. (2008) also noticed that the use of *Azospirillum*, *Rhizobium*, or PSM in cowpea has significantly contributed in translocation of assimilates from leaves and stems to the pods.

Yield parameters

Application of organic manures, biofertilizers and inorganic fertilizers has significant effect on the yield parameters. The non-wrapper leaves, which are the main site for carbohydrates assimilation also impart to head yield. The number of non-wrapper leaves was found insignificant.

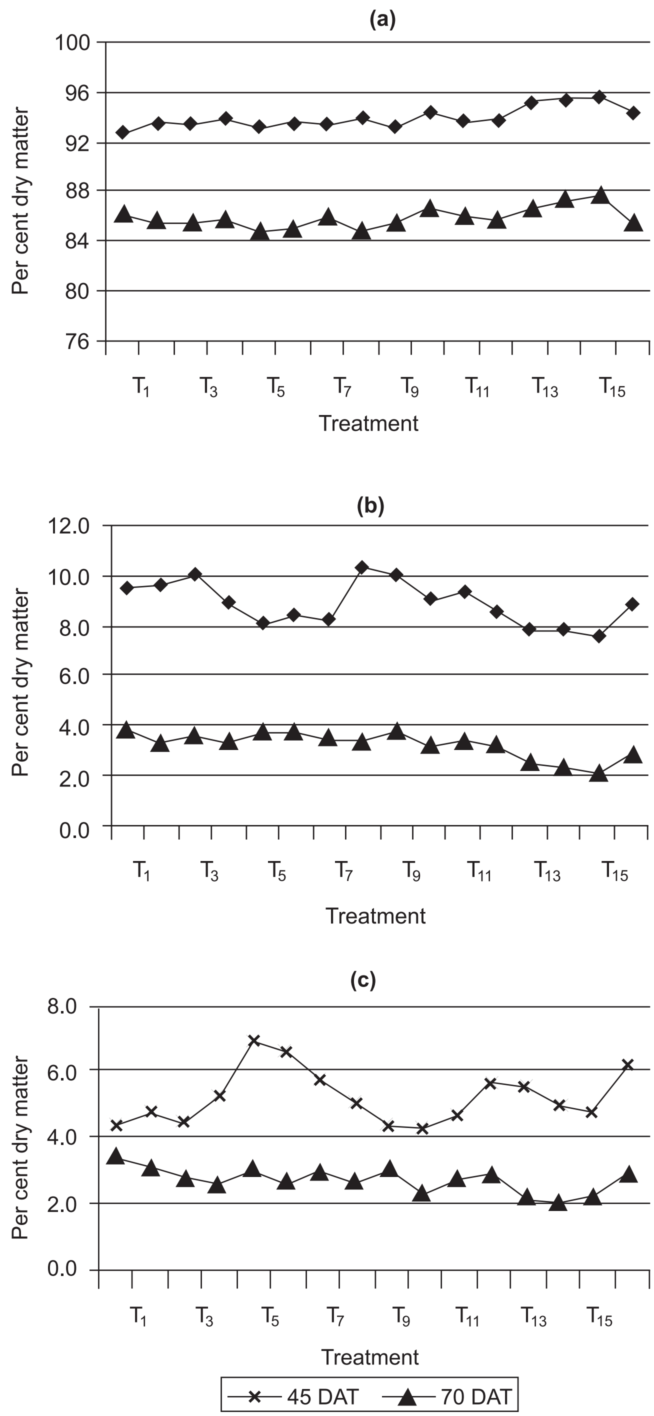

Fig 1 Dry matter partitioning pattern in (*a*) leaves, (*b*) stems and (*c*) roots of cabbage at 45 and 70 days after transplanting.

Table 1 Effect organic manures, inorganic fertilizers and biofertilizers on growth and yield of cabbage

Treatment	Non-wrapper leaves (no.)	Weight of non-wrapper leaves (g)	Wrapper leaves (no.)	Head weight (kg)	Head yield (tonnes/ha)
T_1: FYM 20 tonnes/ ha + *Azospirillum*	13.9	435.18	32.3	1.18	33.02
T_2: FYM 20 tonnes/ ha + VAM	13.3	381.06	28.7	1.16	32.76
T_3: FYM 20 tonnes/ ha + PSM	13.0	401.63	30.0	1.20	33.59
T_4: DS 20 tonnes/ ha + *Azospirillum*	14.8	428.94	33.7	1.20	33.75
T_5: DS 20 tonnes/ ha + VAM	13.2	364.92	28.7	1.18	33.59
T_6: DS 20 tonnes/ ha + PSM	13.1	404.01	31.0	1.22	34.75
T_7: Pressmud 15 tonnes/ ha + *Azospirillum*	14.0	419.81	29.3	1.20	34.13
T_8: Pressmud 15 tonnes/ ha + VAM	12.7	347.50	26.2	1.18	33.25
T_9: Pressmud 15 tonnes/ ha + PSM	13.0	374.28	27.3	1.21	34.23
T_{10}: VC 10 tonnes/ ha + *Azospirillum*	14.0	437.22	32.7	1.22	34.98
T_{11}: VC 10 tonnes/ ha + VAM	13.4	400.26	30.0	1.22	34.56
T_{12}: VC 10 tonnes/ ha + PSM	13.2	410.59	35.3	1.23	35.52
T_{13}: Rec. NPK + *Azospirillum*	15.0	472.18	38.0	1.31	41.22
T_{14}: Rec. NPK + VAM	13.9	452.37	36.0	1.31	40.81
T_{15}: Rec. NPK + PSM	14.6	502.68	39.3	1.32	41.88
T_{16}: Recommended NPK (Control)	13.8	454.39	35.0	1.24	36.63
SE±	0.50	17.56	1.14	0.02	1.07
LSD (P = 0.05)	NS	44.01	3.23	0.05	2.31

Table 2 Effect of organic manures, inorganic fertilizers and biofertilizers on quality traits of cabbage

Treatment	Total carbohydrates (g/100 g)	Protein (g/100 g)	Fibre (g/100 g)	Carotenoids (mg/100 g)	Ascorbic acid (mg/100 g)
T_1: FYM 20 tonnes/ ha + *Azospirillum*	36.72	16.44	16.74	0.407	13.85
T_2: FYM 20 tonnes/ ha + VAM	38.20	15.75	17.20	0.390	14.70
T_3: FYM 20 tonnes/ ha + PSM	40.58	15.31	17.89	0.445	15.48
T_4: DS 20 tonnes/ ha + *Azospirillum*	35.21	17.31	14.92	0.378	13.28
T_5: DS 20 tonnes/ ha + VAM	35.62	16.19	15.56	0.345	13.96
T_6: DS 20 tonnes/ ha + PSM	36.84	15.44	16.45	0.412	14.15
T_7: Pressmud 15 tonnes/ ha + *Azospirillum*	35.97	16.07	15.50	0.352	13.36
T_8: Pressmud 15 tonnes/ ha + VAM	36.76	15.63	15.70	0.334	14.25
T_9: Pressmud 15 tonnes/ ha + PSM	37.90	15.05	16.88	0.397	14.56
T_{10}: VC 10 tonnes/ ha + *Azospirillum*	34.75	17.38	14.62	0.392	13.30
T_{11}: VC 10 tonnes/ ha + VAM	35.45	15.81	14.78	0.368	13.62
T_{12}: VC 10 tonnes/ ha + PSM	36.70	15.70	16.17	0.428	13.85
T_{13}: Rec. NPK + *Azospirillum*	33.25	16.90	13.85	0.324	12.76
T_{14}: Rec. NPK + VAM	34.38	15.12	14.13	0.315	12.95
T_{15}: Rec. NPK + PSM	34.94	14.75	14.48	0.342	13.24
T_{16}: Recommended NPK (Control)	34.54	15.70	14.34	0.330	13.15
SE±	0.79	0.31	0.28	0.009	0.33
LSD (P = 0.05)	2.25	1.12	1.03	0.031	1.07

However, the weight of the non-wrapper leaves was significantly higher in plants supplied with recommended NPK coupled with seedling inoculation in PSM (502.68 g). Similarly, the wrapper leaves that represent head were also affected with the use of biofertilizers and chemical fertilizers. The maximum number of wrapper leaves (39.2±1.14) was reported under recommended NPK + PSM (T_{15}), whereas, the significantly higher head weight and head yield were noticed in all the treatments where recommended NPK was given and seedlings were inoculated with biofertilizer.

Furthermore, the application of pressmud (15 tonnes/ha) or vermicompost (10 tonnes/ha) and seedling inoculation either with *Azospirillum* or PSM registered head yield at par with recommended NPK. The enhancement in head size with combined use of NPK and PSM might be due to the better solubilization of insoluble or fixed P and better replenishment and uptake of soluble P by the plant (Wu *et al*. 2005). Earlier, Bahadur *et al*. (2006, 2009) also noticed improvement in head yield of Chinese cabbage and lettuce with seedling inoculation in PSM or VAM. Since the phosphorus is associated with several vital biochemical functions of the plant, such as utilization of sugar and starch, photosynthesis and root growth, therefore, the positive influence of PSM or VAM might be due to better mobilization and supply of available P for crop growth and other attributes.

Quality parameters

Organic manures and biofertilizers had significant effect on quality parameters of cabbage. The total carbohydrates content was higher under T_2 (38.2 g/100 g), T_3 (40.58 g/100 g), T_6 (36.84 g/100 g) and in T_9 (37.90 g/100 g). Increased total carbohydrates content with the use of PSM or VAM might be due to the fact that these microbes enhance the P availability to plant and P is associated in sugar synthesis and transport. Protein content in head was noticed higher with seedling inoculation with *Azospirillum* and use of either recommended NPK (16.9%) or vermicompost (17.38%) or digested sludge (17.31%). Other treatments have shown protein content at par with control (15.7%). The enhancement in protein content with seedling inoculation in *Azospirillum* might be because of increased P and NH_4^+-N uptake, enhancement of mineral uptake and production of phytohormones such as IAA and gibberellins (Gadagi *et al*. 2004). Fibre content in cabbage head was improved remarkably with use of organic manures and biofertilizers, except in *Azospillum* inoculation and with T_{11}. Soil application of chemical fertilizers and seedling inoculation with biofertilizers had registered fibre content at par with recommended NPK. The carotenoid content was significantly higher in all the organic treatments, except in T_5, T_7 and T_8. Earlier, Bahadur *et al*. (2006) also noticed higher carotenoid content in Chinese cabbage with the use of organic manures and biofertilizers, however, the same organic inputs did not affect the carotenoid content in lettuce (Bahadur *et al*. 2009). So far ascorbic acid (vitamin C) content in head was concerned; the maximum ascorbic acid content was recorded with the use of either FYM or pressmud along with seedling inoculation with either PSM or VAM (T_2, T_3, T_8 and T_9). VA-mycorrhiza and P-solubilizing microbes play an important role in improving P bioavailability (Wu *et al*. 2005). P is helpful in assimilation of carbohydrates, and in turn, the synthesis of ascorbic acid. Furthermore, these microorganisms consume a considerable amount of organic matters, e g, carbohydrates to generate energy for the maintenance and growth (Parr *et al*. 1994, Bulluck *et al*. 2002). Thus, these microbes had better response under present study when they were combined with organic manures.

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