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Effect of FYM, biochar and biofertilizers on head quality and physico-chemical attributes of soil of kharif cabbage (*Brassica oleracea* L. var. *capitata*) cv. pride of India

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Abstract

During the 2018–19 and 2019–20 academic years, at Department of Horticulture, Naini Agricultural Institute of the Sam Higginbottom University of Agriculture, Technology, and Sciences (SHUATS), Prayagraj (U.P.), a field study was conducted. We used a Randomized Block Design with 17 treatments (variations in Inorganic fertilisers, organic manures, and biofertilizers) and 3 replications for this investigation. The main goals of this research were to evaluate head quality and physico-chemical properties of soil of cabbage grown under different levels of Inorganic fertilisers, organic manures, and biofertilizers. Minimum head compactness (23.77%, 21.34%, and 22.56%), maximum Vitamin C (mg/100 g edible portion) (43.82 mg/100 g, 45.32 mg/100 g and 44.57 mg/100 g), T.S.S. (° Brix) (5.71° Brix, 5.54° Brix and 5.63° Brix), N content (%) (0.31%, 0.32%, and 0.31%) and Protein content (%) (1.99%, 2.10%, and 2.05%) were all reported in T_9 (FYM 20 t + 75% NPK + Azotobacter + PSB) over both years and also the pooled analysed data. In relation to soil physico chemical attributes minimum Available Nitrogen (N) (Kg/ha) (164.54 Kg/ha, 166.55 Kg/ha and 165.55 Kg/ha), Available Phosphorous (P) (Kg/ha) (11.6 Kg/ha, 13.73 Kg/ha and 12.67 Kg/ha) and Available Potassium (kg/ha) (208.72 Kg/ha, 211.75 Kg/ha and 210.24 Kg/ha) during both the years and pooled were recorded in T_9 (FYM 20 t + 75% NPK + Azotobacter + PSB).

Keywords: Cabbage, organic manure, FYM, biochar, inorganic fertilizers, quality, head, soil, physico-chemical, azotobacter and PSB

1. Introduction

Cabbage (*Brassica oleracea* L. var. *capitata*) is a green leafy biennial plant, belonging to the family Brassicaceae originating from Mediterranian region. (Katyal and Chadha, 1985) [13]. It's one among India's most widely grown cole crops. The name "cole" was originally applied to a group of related plants that originated from a single wild variety, *Brassica oleracea* var. *sylvestris*, also called colewort or field cabbage. The word "capitata" means "head" in Latin, and that's where the name of this variety originates from. (Chiang *et al.*, 1993) [6].

Cabbage's flavour derives from glucosinolates, which contains anti-cancer sulforaphane (Beecher, 1994) [3]. Cabbage head is digested and is a source of bioavailable protein. The head contains vitamins, minerals, and fibre. It contains vitamin A, B, C nd minerals like P, K, Na, Fe, lipids, and fats (Riba *et al*., 2018) [28]. Russia is the biggest cabbage consumer, followed by China and India (FAOSTAT, 2019). India averages 7,923.89 MT and 22.7 MT/ha cabbage output and productivity (Mishra *et al.*, 2021) [19]. Odisha, Madhya Pradesh, Assam, Bihar, and Gujrat are India's top cabbage producers (NHB, 2020).

Recently, India's cabbage farmers have had to deal with a number of challenges, such as the high cost of inputs, less productive soils, and unfavourable weather conditions. Appiah (2015) [1] found that farmers aren't able to reverse soil-nutrient depletion by adding missing nutrients back into the ground through crop leftovers, manures, and mineral fertilisers. Fertilizers are used to the soil to enrich it with various macro- and micronutrients, which in turn improves plant development and the quality of the crop's head. Soil fertility and quality is tied to biological activity, which is crucial to crop productivity, as pointed out by Stockdale & Watson (2009) [34]. One of the main factors limiting agricultural productivity is the use of an inappropriate fertiliser kind and application rate. Success in meeting consumer demands is a direct result of using the right fertiliser (Ngegba *et al.*, 2020) [21].

Additional plant nutrients, especially nitrogen, are required for cabbage head growth (Ojetayo *et al.*, 2011) [23]. Common practise involves spreading FYM (Farm Yard Manure) on agricultural fields. Soil improved by properly decomposed FYM is beneficial to plant growth. Soil quality can be enhanced by adding biochar, a carbon-rich burnt product. Biochar as a soil supplement is an innovative and potentially fruitful approach to ecologically sound farming **(**Bhatta *et al.*, 2017) [4]. Azotobacter also fixes atmospheric nitrogen in the root zone. This bacterium, which can fix nitrogen in the air, provides an aerobic alternative to inorganic fertiliser. Nitrogen fertiliser consumption can be cut by 10-20% by the application of azotobacter inoculation. PSB (Phosphorous solubilizing bacteria) are a type of microorganism that can convert insoluble P compounds into accessible forms by secreting organic acids; they may be used as inoculants to boost P availability for plants, much like azotobacter (Wang *et al.*, 2014) [40].

Many Indian farmers don't know how to choose and apply fertiliser. Organic, inorganic, and biofertilizers' impacts on cabbage haven't been studied in details. Organic fertilisers promote water retention, nutrient availability, C:N ratio, crop yields, size, flavour, aroma, and quality (Timsina, 2018) [37]. Some research suggests that using more organic manure and less inorganic nitrogen fertiliser will increase cabbage quality. Chemical fertilisers and insecticides have increased vegetable crop productivity in recent decades (Sharma *et al.*, 2008) [30]. Nutrient management affects crop yield and quality. Organic manures improve the soil's physical and nutritional quality and microbial activity. They improve soil characteristics and add nutrients. Decomposition of organics in soil leads to biological processes that prevent disease-causing microorganisms (Ramesh *et al.*, 2010) [25]. Biofertilizers reduce external inputs and improve vegetable quality and quantity. They contain bacteria that can mobilize nutrients through biological processes. Therefore, in light of the foregoing, the current study, named "Effect of FYM, Biochar and biofertilizers on Head quality and Physico-chemical attributes of soil of Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India" was carried out at SHUATS, Prayagraj, Uttar Pradesh.

2. Materials and Methods

In 2018–19 and 2019–20, Kharif Cabbage cv. Pride of India was planted at 60cm×45cm. The experimental area lies 8 km from Allahabad, on the Allahabad-Rewa Road, near the Yamuna River, in the Horticulture Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.).

The experiment has 3 replications for each of the 17 treatment combinations. Table 1 lists details of treatments applied. Each treatment got a unique blend of inorganic, organic (FYM and Biochar), and biofertilizers (Azotobacter and PSB). Quality characteristics, including head compactness (%), vitamin C content (mg/100 g edible portion), T.S.S. (° Brix), Nitrogen content (%) and Protein content (%) & Physico-chemical attributes of soil like Soil pH, Soil organic carbon, Available Nitrogen (N), Available Phosphorous (P) and Available Potassium (K). were effectively measured.

Table 1: Treatment Details & Treatment combinations

S. No.	Treatment	Treatment combinations (%)
1	T_1	100% NPK
2	T_2	Biochar 20 t+75% N+P, K (Recommended)
3	T_3	Biochar 20 t+75% N+P, K Azotobacter
4	T_4	Biochar 20 t+75% N+P, K+PSB
5	T_5	Biochar 20 t+75% N+P, K+ Azotobacter+ PSB
6	T_6	FYM 20 t+75% N+P, K
7	T_7	FYM 20 t+75% N+P, K+ Azotobacter
8	T_8	FYM 20 t+75% N+P, K +PSB
9	T_9	FYM 20 t+75% N+P, K+ Azotobacter+ PSB
10	T_{10}	Biochar 30 t+50% N+P, K
11	T_{11}	Biochar 30 t+50% N+P, K+ Azotobacter
12	T_{12}	Biochar 30 t+50% N+P, K+PSB
13	T_{13}	Biochar 30 t+50% N+P, K+PSB+A zotobacter
14	T_{14}	FYM 30 t+50% N+P, K
15	T_{15}	FYM 30 t+50% N+P, K+ Azotobacter
16	T_{16}	FYM 30 t+50% N+P, K+PSB
17	T_{17}	FYM 30 t+50% N+P, K+PSB+ Azotobacter

3. Results and Discussion

Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India's head quality and physico-chemical attributes of soil were observed and analyzed statistically. Data analysis shows that adding varying amounts of FYM, Biochar, and biofertilizers significantly enhanced all the characteristics except for Soil Ph and Soil organic carbon. It can be seen from the statistics that the variances were statistically significant since F Cal > F Tab.

3.1. Head quality attributes

The results of the observations regarding Head compactness (%) are shown in Table 2; Fig 1. Because of the effects of FYM, biochar, and bio-inoculants on the plant, it was found that the Head compactness (%) had significantly changed. This shows that the treatment T9 (FYM 20 t+75% N+P, K+ Azotobacter+ PSB) recorded the minimum Head compactness (%) [23.77% (2018-19), 21.34% (2019-20) and 22.56% (Pooled)] over all other treatments during both the years of study as well as pooled analysis., while Treatment T10, which consisted of Biochar 30 t+50% N+P, K, recorded significantly the highest Head compactness (%), which was [38.79% (2018-19), 34.83% (2019-20) and 36.81% (Pooled)]. Organic manures improve the soil's physical state due to their slow rate of mineralization, which boosts plant nutrients and provides nutrients throughout the plant's growth cycle.

Azotobacter thrived in the friendly environment provided by FYM. PSB converts insoluble phosphate into soluble forms by producing organic acids. It is one of the most important bacteria for solubilizing nutrients. Photosynthesis requires nitrogen- and phosphorus-containing proteins and chlorophyll. Carbohydrate buildup increased the cabbage head's overall compactness. This may have been induced by more inner leaves and food in the head. This may be because the treated skull's diameter was smaller than its weight, boosting head compactness. The results are in agreement with the findings of Thapliyal *et al*. (2008) [36] in cabbage.

The observations regarding Vitamin C (mg/100 g edible portion) in Table 2; Fig 1. From the data it was observed that the treatment T9 (FYM 20 t+75% N+P, K+ Azotobacter+ PSB) recorded the maximum vitamin C content in cabbage (43.82 mg, 45.32 mg and 44.57 mg/100 g edible portion) during both the years of study as well as pooled analysis respectively, while The lowest vitamin C content (36.47 mg, 38.48 mg, 37.47 g/100 g edible portion) in cabbage was recorded in treatment T_{10} (Biochar 30 t+50% N+P, K). Azotobacter and PSB boost vitamin C content. These bio inoculants produce growth chemicals that modulate soil enzymes, maximizing Nitrogen availability for all physiological processes (Davis *et al*., 2004) [8]. Nitrogen and Phosphorus synthesis carbohydrates. Ascorbic acid (Vitamin C) is a carbohydrate, therefore plant production increases (Divya *et al*., 2015) [9]. Biochar with 50% N+P, K cannot give plants with constant Nitrogen, unlike FYM and bio inoculants. The nitrogen is also supplied at 50% of the typical suggested amount, so the plant tries to utilise it efficiently by partitioning it for protein synthesis and not for carbohydrate synthesis, which decreases ascorbic acid content (Singh and Singh, 2019) [32].

The data regarding T.S.S. (° Brix) is shown in Table 2; Fig 2. From the data it was observed that treatment T_{ss} (FYM 20 t+75% N+P, K+ Azotobacter+ PSB) recorded the maximum Total Soluble Solids [5.71° Brix (2018-19), 5.54° Brix (2019-20) and 5.63° Brix (Pooled)] over all other treatments during both the years of study as well as pooled analysis., while the lowest Total Soluble Solids [5.47° Brix (2018-19), 5.24° Brix (2019-20) and 5.36° Brix (Pooled)] were recorded in T10 (Biochar 30 t+50% N+P, K). From the aforementioned observations, it can be inferred that adding FYM @20 t combined with Azotobacter and PSB with 75% of the required dose of Nitrogen, Potassium, and Phosphorous increases cabbage TSS. This may be attributed to a progressive and consistent supply of macronutrients to the plants, which boosted carbohydrate production efficiency and led to greater Total soluble solids (Kumar *et al*., 2011) [14]. Due to greater soil conditioning from FYM, plants' nitrogen utilization efficiency rose (Kumar *et al*., 2019) [15]. Biochar treatment immobilizes nutrients, notably nitrogen, reducing the plant's nutrition utilization efficiency and TSS (Frenkel *et al*., 2017) [11].

The observations regarding N content (%) has been depicted in Table 2; Fig 2. From the data it was observed that the treatment T9 (FYM 20 t+75% N+P, K+ Azotobacter+ PSB) recorded the maximum N content [0.31% (2018-19), 0.32% (2019-20) and 0.31% (Pooled)] over all other treatments during both the years of study as well as pooled analysis, while the lowest Total N content [0.21% (2018-19), 0.24% (2019-20) and 0.23% (Pooled)] were recorded in T10 (Biochar 30 t+50% N+P, K). From the aforementioned observations, it can be inferred that adding FYM @20 t combined with Azotobacter and PSB with 75% of the necessary dose of Nitrogen, Potassium, and Phosphorous increases cabbage's Nitrogen content. Maximum nitrogen in cabbage heads may occur from Azotobacter's air nitrogen fixation and PSB's solubilization of the soil's native phosphate status, providing an optimally nutrient-available root system and soil plant system (Baral and Adhikari, 2013) [2]. It's well-known that nutrient availability in a plant's feeding zone affects its growth. Biofertilizers boost the nitrogen and phosphorus accessible to plants, promoting root growth and nutrient cycling in the soil (Poonia and Dhaka, 2012) [24]. Maximum Nitrogen availability causes cabbage head Nitrogen buildup.

The data regarding Protein content (%) is shown in Table 2; Fig 2. From the data it was observed that treatment T_9 (FYM 20 t+75% N+P, K+ Azotobacter+ PSB) recorded the maximum Protein content [1.99% (2018-19), 2.10% (2019-20) and 2.05% (Pooled)] over all other treatments during both the years of study as well as pooled analysis, while the lowest Protein content [1.37% (2018-19), 1.58% (2019-20) and 1.48% (Pooled)] were recorded in T10 (Biochar 30 t+50% N+P, K). From the aforementioned observations, it can be inferred that adding FYM @ 20 t combined with Azotobacter and PSB with 75% of the necessary dose of Nitrogen, Potassium, and Phosphorous increases cabbage's Nitrogen content. The protein increase may be related to the crop's root zone having improved access to nitrogen (N) due to FYM's breakdown making N more soluble (Regar *et al*., 2018) [27]. Since cabbage's protein composition is proportional to its nitrogen concentration, plants need optimal continuous nitrogen supply. Bio-fertilizers can convert atmospheric nitrogen gas into a form that plants can utilize, improving cabbage's nutrient uptake (Singh and Rai, 2004) [33].

3.2. Physico-Chemical Attributes of Soil

Table 3 displays the collected data in terms of Soil pH during the year 2018-19 and 2019-20, where it was observed that there were insignificant changes in pH due to the effect of FYM, biochar and bio-inoculants on the soil pH. This shows that pH of soil more or less remained same for all the treatments. However, the pooled analysis for data showed significant differences in pH due to different treatment combinations. According to pooled data, maximum Soil pH of 7.29 was observed in Treatment T_{10}, T_{11}, T_{16}, T_{17}, T_3, T_4, T_6 and T_7 whereas minimum soil pH of 7.27 was observed in T1. Most of Nitrogen applied through inorganic fertilization is lost due to leaching and volatilization. Higher nitrogen doses lower soil pH. (Tkaczyk *et al*., 2020) [38]. Since inorganic fertilizers supplied less nitrogen than suggested, the soil pH increased. Bio-inoculants like Azotobacter and PSB fixed nitrogen and phosphorus, improving the soil-plant nutrient cycle (Sun *et al*., 2020) [35]. Bio-inoculants stabilized N and P volatilization losses. FYM improved soil structure and base saturation, which raised soil acidity (Zhang *et al*., 2009) [39]. Biochar has limiting potential due to its high base cation concentrations and proton consumption capacity, reducing soil acidity and increasing pH. (Chintala *et al*., 2014) [7].

Table 3 displays the collected data in terms of Soil Organic Carbon content (%) during the year 2018-19 and 2019-20, where it was observed that there were insignificant changes in soil organic carbon content due to the effect of FYM, biochar and bio-inoculants. However, the pooled analysis for data showed significant differences in soil organic carbon due to the effect of different treatment combinations. According to pooled data, Soil Organic Carbon content of 0.5% was observed in Treatment T_{10}, T_{11}, T_{16}, T_{17}, T_3, T_4, T_6 and T_7 whereas lowest Soil Organic Carbon content of 0.48% was observed in T_1. Plant growth depends on soil organic matter (Lee *et al*., 2009) [17]. According to previous studies, adding organic matter increases soil organic carbon. FYM and inorganic fertilizers improve soil porosity, bulk density, and aggregate stability (Lee *et al*., 2009) [17]. Better soil structure and texture may have boosted microbial proliferation. These microorganisms decompose FYM and release organic carbon into the soil (Sanchez *et al*., 1989) [29]. Azotobacter and PSB may have helped organic carbon accumulation in soil by generating organic acids that degrade organic materials to release carbon (Goel and Bano, 2020) [12].

The observations regarding the Available Nitrogen (Kg/ha) during the year 2018-19 and 2019-20 are shown in Table 3; Fig 3. T10 (Biochar 30 t+50% N+P, K) had highest available Nitrogen [173.82 kg/ha (2018-19), 175.83 kg/ha (2019-20) and 174.83 kg/ha (pooled)] than rest other treatments in both the years of study as well as pooled analysis., while The lowest available Nitrogen [164.54 kg/ha (2018-19), 166.55 kg/ha (2019-20) and 165.55 kg/ha (pooled)] in soil was reported for treatment T9. Biochar increases residual Nitrogen availability in T10 plots. Biochar can trap ammonia (NH3) and immobilise it, increasing soil nitrogen (Singh *et al*., 2018). Biochar's micropores and high surface charge capture NO3- and NH4+ ions. Biochar improved CEC and AEC, which helped immobilise nitrogen (Singh *et al*., 2018). T9 had the least accessible nitrogen because biofertilizers enhanced the roots' Nitrogen usage efficiency (NUE), reducing soil Nitrogen availability.

The observations regarding the Available Phosphorous (kg/ha) during the year 2018-19 and 2019-20 are shown in Table 3; Fig 3. it was observed that the treatment plots soil of T10 (Biochar 30 t+50% N+P, K) had highest available Phosphorous [15.29 kg/ha (2018-19), 17.46 kg/ha (2019-20) and 16.38 kg/ha (pooled)] than rest other treatments in both the years of study as well as pooled analysis, while lowest available Phosphorous [11.60 kg/ha (2018-19), 13.73 kg/ha (2019-20) and 12.67 kg/ha (pooled)] in soil was reported for treatment T9. Biochar increases residual Phosphorous availability in T10 plots. Biochar can absorb organic phosphorus molecules including orthophosphates, decreasing phosphorus leaching (Laird *et al*., 2010) [16]. Due to high temperatures during Biochar synthesis, organic phosphorous bonds may be cleaved and Phosphorous levels may rise (Novak *et al*., 2009) [22].

The observations regarding the Available Potassium (Kg/ha) during the year 2018-19 and 2019-20 are shown in Table 3; Fig 3. T_{10} (Biochar 30 t+50% N+P, K) had highest available Potassium [218.01 kg/ha (2018-19), 221.23 kg/ha (2019-20) and 219.62 kg/ha (pooled)] than rest other treatments in both the years of study as well as pooled analysis, while lowest available Potassium [208.72 kg/ha (2018-19), 211.75 kg/ha (2019-20) and 210.24 kg/ha (pooled)] in soil was reported for treatment T_9. Biochar increases residual potassium availability in T_{10} plots. Potassium is inorganic in charcoal and liberated as soluble and exchangeable fractions after incorporation (Rasuli *et al*., 2022) [26]. Biochar's high surface area, high negative charges on particle surfaces, and porous structure allow it to retain potassium in exchangeable forms, according to studies (Cheng *et al*., 2008; Major *et al*., 2012) [5, 18]. Biochar enhances soil CEC (Cation Exchange Capacity), which provides more exchangeable sites for potassium adsorption (Rasuli *et al*., 2022) [26]. T9 [FYM 20 t+75% N+P, K+ Azotobacter+ PSB] had reduced accessible potassium because bio-fertilizers like Azotobacter and PSB emit organic acids (Sun *et al*., 2020) [35] that solubilize potassium and make it available to plant roots for absorption, resulting in low soil potassium content.

Table 2: Effect of FYM, Biochar and biofertilizers on Head quality attributes of Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India

Treatment Symbol	Head compactness (%)			Vitamin C (mg/100 g edible portion)			T.S.S. (° Brix)			N content (%)			Protein content (%)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_1	29.09	26.12	27.60	39.65	41.46	40.56	5.56	5.34	5.45	0.25	0.28	0.26	1.63	1.81	1.72
T_2	28.61	25.69	27.15	40.87	42.68	41.78	5.61	5.40	5.51	0.26	0.29	0.28	1.72	1.88	1.80
T_3	26.20	23.53	24.86	41.79	43.48	42.64	5.65	5.46	5.56	0.28	0.30	0.29	1.83	1.97	1.90
T_4	26.26	23.58	24.92	41.46	43.14	42.30	5.64	5.45	5.55	0.28	0.30	0.29	1.79	1.93	1.86
T_5	26.56	23.85	25.21	42.01	43.69	42.85	5.67	5.48	5.58	0.28	0.31	0.30	1.88	1.99	1.94
T_6	26.49	23.78	25.14	41.24	42.92	42.08	5.63	5.42	5.53	0.27	0.29	0.28	1.75	1.91	1.83
T_7	23.76	21.34	22.55	43.09	44.59	43.84	5.70	5.53	5.62	0.30	0.32	0.31	1.97	2.08	2.03
T_8	25.24	22.67	23.95	42.77	44.38	43.58	5.69	5.52	5.61	0.30	0.32	0.31	1.94	2.05	2.00
T_9	23.77	21.34	22.56	43.82	45.32	44.57	5.71	5.54	5.63	0.31	0.32	0.31	1.99	2.10	2.05
T_{10}	38.79	34.83	36.81	36.47	38.48	37.47	5.47	5.24	5.36	0.21	0.24	0.23	1.37	1.58	1.48
T_{11}	34.62	31.09	32.85	38.42	40.33	39.38	5.51	5.29	5.40	0.23	0.26	0.25	1.51	1.71	1.61
T_{12}	34.63	31.10	32.86	37.61	39.62	38.62	5.50	5.27	5.39	0.23	0.26	0.24	1.48	1.68	1.58
T_{13}	28.87	25.92	27.39	39.86	41.67	40.77	5.58	5.37	5.48	0.25	0.28	0.27	1.64	1.84	1.74
T_{14}	38.02	34.14	36.08	36.90	38.91	37.91	5.48	5.25	5.37	0.22	0.25	0.23	1.41	1.62	1.52
T_{15}	30.03	26.96	28.50	39.47	41.38	40.43	5.54	5.32	5.43	0.24	0.27	0.26	1.59	1.77	1.68
T_{16}	32.84	29.49	31.17	39.10	41.01	40.06	5.53	5.31	5.42	0.24	0.27	0.25	1.53	1.73	1.63
T_{17}	29.85	26.80	28.33	40.22	42.00	41.11	5.59	5.38	5.49	0.26	0.28	0.27	1.68	1.82	1.75
F-test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
S.E. (m) (±)	1.35	1.21	0.9	0.29	0.22	0.18	0.01	0.01	0.01	0	0	0.002	0.03	0.03	0.02
C.D. @ 5%	3.89	3.5	2.56	0.84	0.64	0.51	0.03	0.03	0.03	0.01	0.01	0.007	0.08	0.09	0.06
C.D. @ 1%	5.23	4.7	3.4	1.12	0.86	0.68	0.04	0.04	0.04	0.01	0.01	0.009	0.11	0.13	0.08
Treatment*Year	NS			NS			*			NS			NS		

Table 3: Effect of FYM, Biochar and biofertilizers on Physico-chemical attributes of soil of Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India

Treatment Symbol	Soil pH			Soil organic carbon (%)			Available Nitrogen (N) (Kg/ha)			Available Phosphorous (P) (Kg/ha)			Available Potassium (kg/ha)		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T_1	7.21	7.32	7.27	0.47	0.48	0.48	168.13	170.14	169.14	13.16	15.17	14.17	212.13	215.15	213.64
T_2	7.22	7.33	7.28	0.48	0.49	0.49	167.69	169.70	168.70	12.99	15.03	14.01	211.80	214.80	213.30
T_3	7.23	7.34	7.29	0.49	0.50	0.50	166.68	168.69	167.68	12.45	14.56	13.51	210.76	213.79	212.28
T_4	7.23	7.34	7.29	0.49	0.50	0.50	167.01	169.02	168.02	12.67	14.75	13.71	211.16	214.20	212.68
T_5	7.22	7.33	7.28	0.48	0.49	0.49	166.27	168.28	167.28	12.32	14.46	13.39	210.41	213.48	211.95
T_6	7.23	7.34	7.29	0.49	0.50	0.50	167.31	169.32	168.32	12.82	14.88	13.85	211.48	214.49	212.99
T_7	7.23	7.34	7.29	0.49	0.50	0.50	164.88	166.89	165.89	11.81	13.88	12.85	209.01	212.03	210.52
T_8	7.22	7.33	7.28	0.48	0.49	0.49	165.27	167.28	166.28	11.91	14.06	12.99	209.35	212.39	210.87
T_9	7.22	7.33	7.28	0.48	0.49	0.49	164.54	166.55	165.55	11.60	13.73	12.67	208.72	211.75	210.24
T_{10}	7.23	7.34	7.29	0.49	0.50	0.50	173.82	175.83	174.83	15.29	17.46	16.38	218.01	221.23	219.62
T_{11}	7.23	7.34	7.29	0.49	0.50	0.50	171.66	173.67	172.67	14.44	16.53	15.49	215.80	218.81	217.31
T_{12}	7.22	7.33	7.28	0.48	0.49	0.49	172.20	174.21	173.21	14.68	16.78	15.73	216.33	219.37	217.85
T_{13}	7.22	7.33	7.28	0.48	0.49	0.49	170.68	172.69	171.69	14.02	16.14	15.08	214.73	217.75	216.24
T_{14}	7.22	7.33	7.28	0.48	0.49	0.49	173.18	175.19	174.19	15.09	17.26	16.18	217.20	220.20	218.70
T_{15}	7.22	7.33	7.28	0.48	0.49	0.49	168.57	170.58	169.58	13.30	15.31	14.31	212.68	215.68	214.18
T_{16}	7.23	7.34	7.29	0.49	0.50	0.50	169.23	171.24	170.24	13.46	15.51	14.49	213.36	216.39	214.88
T_{17}	7.23	7.34	7.29	0.49	0.50	0.50	170.21	172.22	171.22	13.87	15.88	14.88	214.29	217.29	215.79
F-test	NS	NS	S	NS	NS	S	**	**	**	**	**	**	**	**	**
S.E. (m) (±)	0.01	0.01	0.004	0.01	0.01	0.004	0.42	0.42	0.29	0.14	0.14	0.09	0.42	0.41	0.29
C.D. @ 5%	NS	NS	0.011	NS	NS	0.011	1.2	1.2	0.83	0.4	0.41	0.28	1.2	1.18	0.82
C.D. @ 1%	NS	NS	0.015	NS	NS	0.015	1.62	1.61	1.1	0.54	0.55	0.37	1.62	1.59	1.09
Treatment*Year	NS			NS			NS			NS			NS		

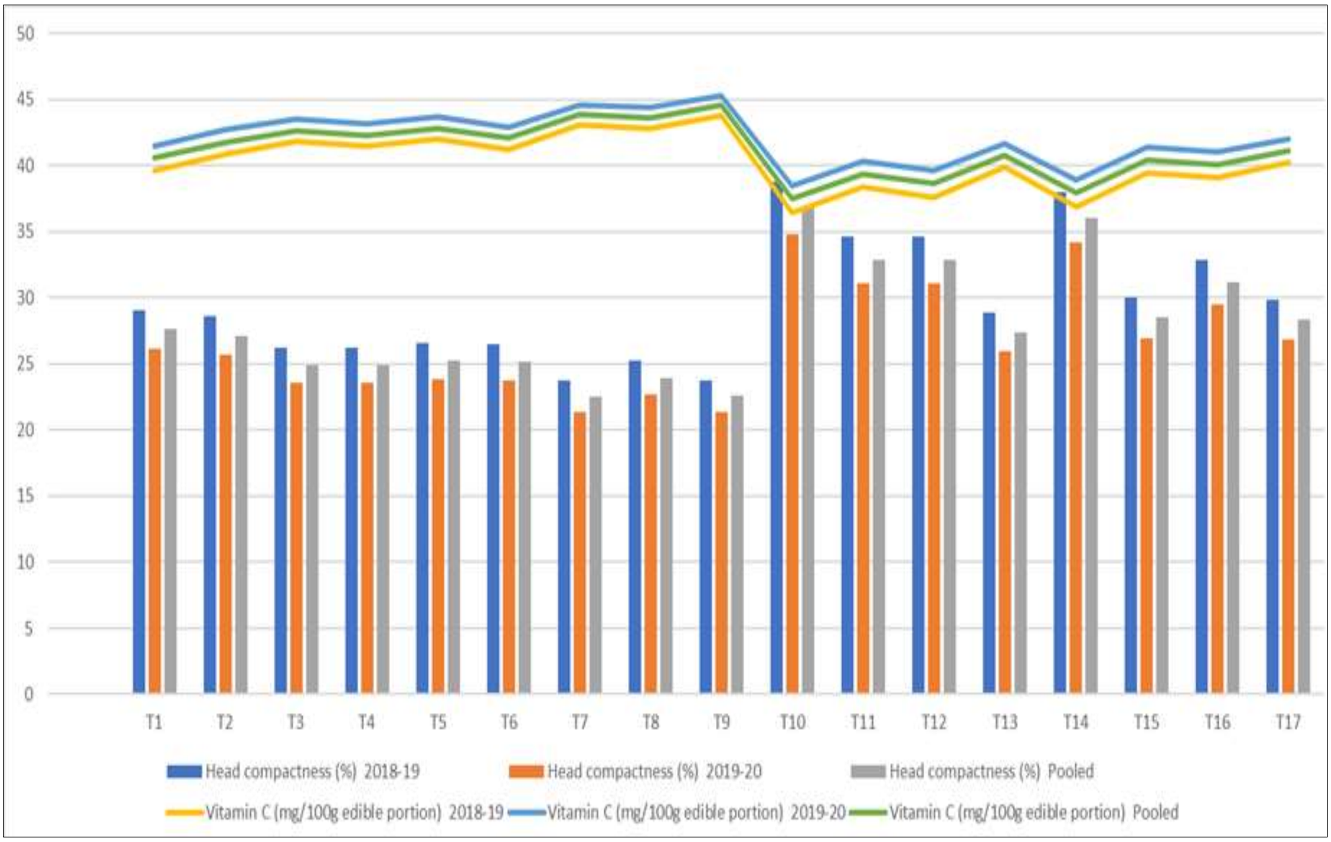

Fig 1: Effect of FYM, Biochar and biofertilizers on Head compactness (%) and Vitamin C (mg/100 g edible portion) of Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India

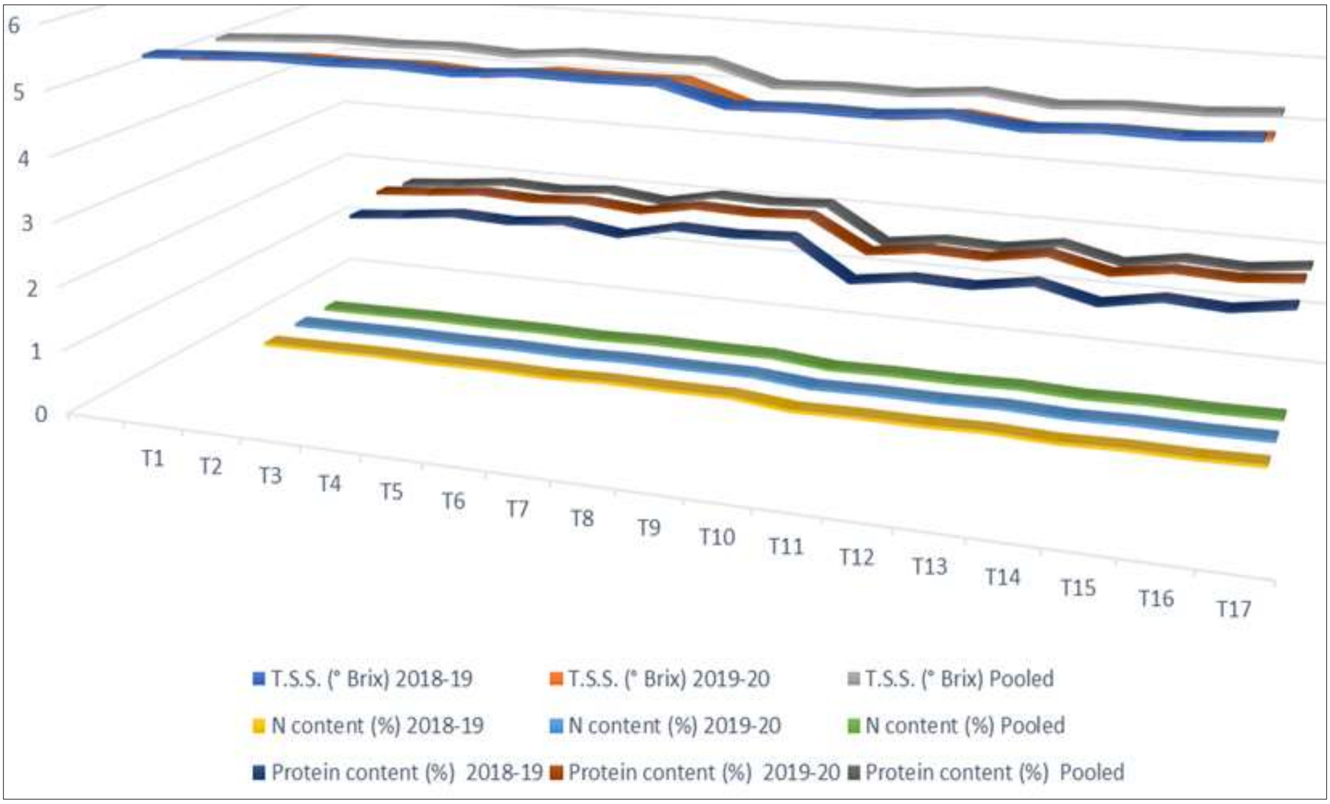

Fig 2: Effect of FYM, Biochar and biofertilizers on T.S.S. (° Brix), Nitrogen content (%) and Protein content (%) of Kharif Cabbage (*Brassica oleracea* L. var. capitata) cv. Pride of India

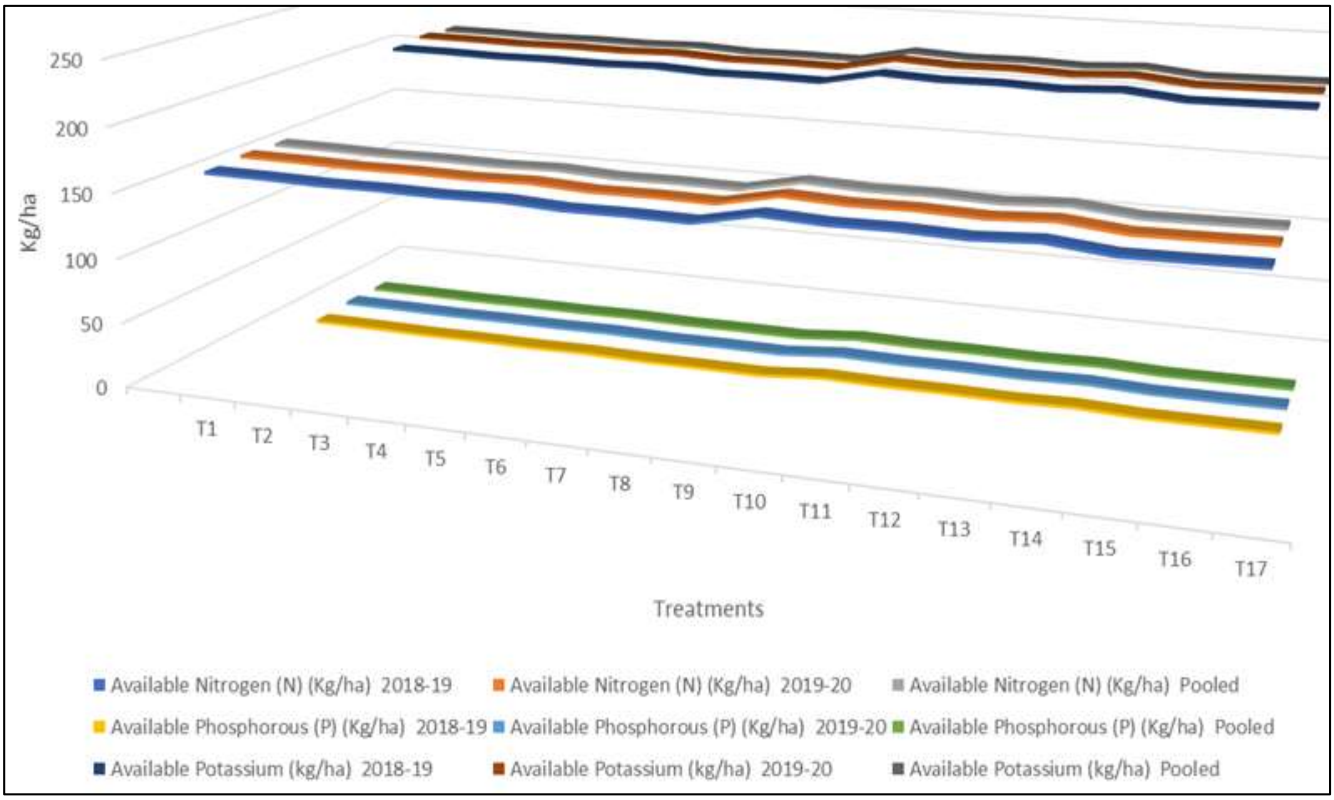

Fig 3: Effect of FYM, Biochar and biofertilizers on Available Nitrogen (N), Available Phosphorous (P) and Available Potassium (K) of Kharif Cabbage (*Brassica oleracea* L. var. *capitata*) cv. Pride of India

Conclusion

From the current experiment, Treatment T_9 i.e., (FYM 20 t+75% N+P, K+ Azotobacter+ PSB), had the best effects. It was deemed to have the best head quality characteristics, including head compactness (%), vitamin C content (mg/100 g edible portion), T.S.S. (° Brix), Nitrogen content (%) and Protein content (%) & Physico-chemical attributes of soil like Soil pH, Soil organic carbon, Available Nitrogen (N), Available Phosphorous (P) and Available Potassium (K)

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