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Yield and phytochemical content of broccoli under different nutrient management in acidic soils on hill terrace

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Abstract
Nutrient management is one of the major challenges in organic farming practices. This study assessed how different forms of nutrient management can influence yield and quality of broccoli as a part of M.Sc., research programme. Application of organic manures and inorganic fertilizers either alone or in combination increased yield and contents of the phytochemicals of broccoli significantly compared to that in no-input plot. Application of vermicompost with FYM and bioinoculants along with 100%K increased broccoli head yield which was at par with that in 100% NPK alone and increased the contents of phytochemicals significantly compared to that in all other nutrient management practices. Findings of this study clearly revealed higher content of phytochemicals in broccoli head was achieved under organic manure with bioinoculants application and this nutrient management practice may be recommended for organically grown broccoli in acidic soils on hill terrace.

Keywords: Broccoli, yield, phytochemicals, nutrient, hill terrace

Introduction
The rainfed hill agro ecosystem in the North Eastern Region is almost organic by default, which are suitable for growing high value commercial crops. Broccoli cultivation can be promoted in these areas because the temperature requirement for growth and development of broccoli is conducive. Broccoli is well known for high nutritional value, high contents of antioxidants, vitamin A, vitamin B_2 and calcium (Singh *et al*., 2006) [9]. Though, soil nutrient management is an important aspect in achieving high yield and quality of broccoli, the information on nutrient management of broccoli in acidic soils of hill terraces in the northeastern region is lacking. Now-a-days, farmers are frequently advised to apply organic residues, inorganic fertilizers and bio-inoculants in combination to achieve higher crop productivity without deteriorating soil health (Chhonkar, 2003) [2]. The aim of this investigation was to assess the yield and quality (phytochemicals) of broccoli under various forms of nutrient management practices in comparison to that in recommended inorganic fertilizers practice.

Materials and Methods
The experiment was carried out on hill terrace at the experimental farm of Division of Horticulture, ICAR Research Complex for NEH Region (25° 41`-21`` N, 91° 55`-25`` E and 1010 m above msl) located at Umiam, Meghalaya, India. The crop growing period was September 2009 to February 2010 with relative humidity of 70 to 85% (morning) and 55 to 65% (evening), ambient temperature ranged from 20 to 24°C (max) and 7 to 16° C (min). The average monthly rainfall received during September 2009 was 140mm and then, no rainfall received from November 2009 to till the end of crop growing period. Soil of experimental field was sandy loam and some basic soil properties are: pH-4.8, organic carbon-1.82%, nitrogen (N)-203.9 kg ha^{-1}, phosphorus (P) -19.7 kg ha^{-1} and potassium (K) – 136.5 kg ha^{-1}.The experimental field was divided into three blocks and each block consisted of eight plots (each plot area was 3 m^2). The eight different nutrient management treatments were: (1) control (2) Vermicompost (VC) @ 2 t ha^{-1} + FYM @ 5 t ha^{-1}, (VC + FYM), (3) Recommended NPK fertilizers (80:100:100 kg ha^{-1}), (100%NPK), (4) 50% of recommended dose of NPK + 50% of VC+FYM, (½NPK + ½ VC+FYM), (5) 25% lime + ½NPK (¼L + ½NPK), (6) ¼L + ½NPK + ½VC + FYM, (7) ¼L + VC + FYM and (8) VC + FYM+ R*azo*B +. + 100% K.

Seedlings of broccoli cv. Pushpa were raised on nursery beds (3 m x 1 m x 15 cm) followed by transplantation (45 cm x 30 cm) on main field. Five plants were harvested randomly from each plot for determination of average head weight (g), average tap root length (cm) per plant and phytochemicals content in curd. The harvested curds were immediately stored at 2°C for determination of phytochemicals *viz.* ascorbic acid, β-carotene, total chlorophyll and total phenol contents. Total curd yield (kg) per plot was recorded. The ascorbic acid content was determined by the method described by Jagota and Dani (1982) [5]. The concentration of ascorbic acid in the sample was calculated from the slope of the ascorbic acid standard curve. β-carotene was determined as per procedure described by Srivastava and Kumar (2002) [10]. Total chlorophyll content was determined by using the colorimetric method described by Singh *et al.* (2006) [9]. The total phenol content was determined by the method described by Malick and Singh (1980) [7]. The concentration of phenols in the test sample was calculated from the standard curve and expressed as mg phenols/100 g material.Statistical analysis of the data was carried out by the method of analysis of variance as outlined by (Gomez and Gomez, 1983) [4].

Result and Discussion

Application of VC+FYM either alone or with bioinoculants showed the maximum positive effect in terms of increase in average tap root length per plant compared to that in plots under inorganic nutrient management (Table 1). Increase in tap root length was also recorded under biofertilizers applied treatment plot in case of tomato (Kumarswamy and Madalageri, 1990) [6] and in pepper (Arisha *et al.*, 2003) [1]. Average curd weight per plant differed significantly between nutrient management plots (Table 1). Average curd weight per broccoli plant in VC+FYM, 100% NPK, VC+FYM+RazoB+P5+100%K and ½NPK+½VC+FYM plots increased by 10.5%, 15.0%, 18.6% and 24.4%, respectively over that in control plot. Similarly, yield of broccoli per plot increased by 22.9%, 37.0%, 40.0% and 48.6% in VC+FYM, 100% NPK, VC+FYM+RazoB+PSB+100%K and ½NPK+½VC+FYM plots, respectively over that in control plot and effects were significant (P<0.05, Table 1). These results indicated that the addition of inputs in the forms of organic or inorganic alone or in combination is necessary in improving the yield of broccoli in acidic soils of hill terraces. The differences in yields of broccoli in 100%NPK, ½NPK+½VC+FYM and VC+FYM+RazoB+PSB+100%K plots were non-significant (P>0.05, Table 1). Our findings corroborate the results of a long term experiment reported by Ramesh *et al.* (2010) [8] that combined application of cowdung + vermicompost increased the yield of chickpea (1766 kg ha^{-1})which was at par with the yield (1693 kg ha^{-1}) obtained by the recommended dose of inorganic fertilizers. Inclusion of biofertilizers (Azotobacter and PSB) along with VC+FYM in the VC+FYM+RazoB+PSB+100%K plot increased yield of broccoli by 14% over that in VC+FYM plot and a comparable yield (increased by 2% only) over that in 100% NPK plot. These findings clearly indicated that the combined use of inorganic fertilizers and organic residues supported higher yield of broccoli in acidic soils of hill terrace.

The combined use of organic residues and inorganic fertilizers or organic residues and biofertilizers improved quality of broccoli curd in terms of the content of phytochemicals significantly (P<0.05) compared to that in broccoli curds obtained from organic residues or inorganic fertilizers alone applied pots (Table 2). Broccoli curds contained significant higher amount of ascorbic acid, β-carotene, chlorophyll and total phenol in VC+FYM+RazoB+PSB+100% K plot in comparison to that in other nutrient management plots. Previous study reported that inoculation of sweet pepper with *Azospirillum brasiliense* and *Pantoea dispers* increased the concentration of citric acid, ascorbic acid in green fruits compared with non-inoculated fruits under limited N supply (Del Amor *et al*., 2008) [3].

Conclusion

The study has confirmed that the combined use of the bioinoculants *i.e. Azotobacter* (isolate R*azo*B) and phosphate solubilizing bacteria (MTCC4714) with organic manure and 100% K is an optimum nutrient management practice for broccoli cultivation in obtaining higher yield, better quality and improving soil quality in acidic soil of hill terrace in NEH region.

Table 1: Effect of nutrient management treatments on growth and yield of broccoli grown in micro-plots on hill terrace

Treatment	Head weight per plant(g)	Tap root length per plant (cm)	Yield per plot (kg)	Yield per hectare (q)
Control	286.7	15.7	3.5	115.6
VC+FYM	316.7	19.0	4.3	144.4
100%NPK	330.0	17.3	4.8	158.9
½ NPK+ ½ VC+FYM	356.7	18.3	5.2	174.4
¼ L+ ½ NPK	310.0	16.7	3.8	126.7
¼ L+ ½ NPK+ ½ VC+FYM	353.3	18.0	5.1	170.0
¼ L+VC+FYM	320.0	20.3	4.2	140.0
VC+FYM+R*azo*B+PSB+100%K	340.0	21.0	4.9	162.2
SE(m) ±	3.3	1.1	0.2	7.0
$CD_{0.05}$	7.2	2.4	0.5	15.1
CV (%)	1.2	7.4	5.7	5.7

Table 2: Effect of nutrient management treatments on the content of phytochemicals in broccoli grown in micro-plots on hill terrace

Nutrient management regimes	AA	BC	CC	TP
	mg/100g [fw] head	mg/100g[fw] head	mg/g [fw] head	mg/100g [fw] head
Control	67.2	21.6	0.25	78.0
VC+FYM	68.1	25.6	0.32	79.4
100%NPK	71.0	28.6	0.33	80.9
½ NPK+ ½ VC+FYM	73.3	29.6	0.35	81.4
¼ L+ ½ NPK	72.0	22.5	0.32	80.7
¼ L+ ½ NPK+ ½ VC+FYM	73.7	30.2	0.33	81.5

¼ L+VC+FYM	69.4	25.4	0.32	79.4
VC+FYM+R*azo*B+PSB+100%K	75.0	32.4	0.35	83.1
SE(m) ±	0.6	0.2	0.008	0.7
$CD_{0.05}$	1.3	0.4	0.02	1.5

[AA- Ascorbic acid, BC- β-carotene, CC- Chlorophyll content, TP- Total phenol.]

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