Comparative performance of organic and inorganic fertilizers on plant growth, head yield, soil health and severity of black rot in sprouting broccoli cv Green Head

PRINCE KUMAR, ML BHARDWAJ, DHARMINDER KUMAR, RAMESH KUMAR, D TRIPATHI*, KS THAKUR, N BHARAT, NIDHISH GAUTAM, SANDEEP KUMAR and BALBIR DOGRA**

Department of Vegetable Science, *Department of Soil Science and Water ManagementDepartment of Plant Pathology**
Dr YS Parmar University of Horticulture and Forestry
Nauni, Solan 173230 Himachal Pradesh, India
Email for correspondence: dharmruder@gmail.com

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ABSTRACT

Sustainable vegetable production, soil health management and low cost production technology are the main issues getting attension in the last few decades. Therefore two years' field experiments were conducted at the experimental farm of Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Rabi season of 2011-12 and 2012-13 to assess the comparative performance of organic and inorganic fertilizers and integrated nutrient management on growth, head yield, soil health and severity of black rot in sprouting broccoli cv Green Head. The experiment was laid out in randomized complete block design having twenty five treatments comprising organic (FYM, neem manure and vermicompost), inorganic (N, P and K), biofertilizers (*Azotobacter* and PSB) and integrated nutrient management (complementary use of organics, biofertilizers and inorganic fertilizers) with three replications. The pooled analysis revealed that head yield was maximum with the treatment combination of biofertilizers with recommended dose of fertilizers whereas plant height at maturity, number of leaves per plant, available soil nitrogen, phosphorus and potassium were exhibited significantly higher in treatment combination of 33.3 per cent recommended dose of fertilizers + 33.3 per cent farmyard manure + 33.3 per cent vermicompost + biofertilizers. Minimum days taken to 50 per cent heading and lesser severity of black rot were also recorded in the same treatment.

Keywords: Sprouting broccoli; soil health; disease severity; head yield

INTRODUCTION

Sprouting broccoli (*Brassica oleracea* L var *italica* Plenck) is one of the most important exotic vegetables recently introduced in Indian sub-continent. It belongs to the family Cruciferae and is very nutritious vegetable crop containing vitamin A content 130 times more than cauliflower, vitamin C content 22 times more than cabbage and having anticancerous property due to the presence of sulphoraphane and glucoraphanin (Thamburaj and Singh 2001). Production potential of any crop increases manifold by synthetic fertilizers. Excessive use of these fertilizers causes imbalance in ecological and soil environment. Organic manures and biofertilizers have proven best for soil fertility and productivity. Scientific information on production of sprouting broccoli is meagre. Complementry use of organic manures and biofertilizers with inorganic fertilizers is the present need for the sustainable vegetable production. Hence the present investigation was carried out to study the comparative efficiency of organic manures, biofertilizers, inorganic fertilizers and integrated nutrient management on growth, head yield, soil health and severity of black rot of sprouting broccoli cv Green Head.

MATERIAL and METHODS

The field experiment was carried out at the experimental research farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni Solan, Himachal Pradesh during Rabi season of 2011-12 and 2012-13 in randomized complete block design. The farm area falls in the mid-hill sub-humid and sub-temperate climate. During the two growing seasons the mean rainfall was 230.40 and 271.70 mm and mean of daily temperature maxima and minima were 28.32°C and 27.70°C and 14.92°C and 17.0°C. The initial soil physico-chemical properties are presented in Table 1. Cultivar Green Head of sprouting broccoli was chosen. There were of 25 treatments (Table 2) which consisted of sole application of organic sources (vermicompost, neem manure and farmyard manure), biofertilizers (*Azotobacter* and phosphate solubilizing bacteria), inorganic fertilizers (N, P and K) and their combinations with three replications. The entire calculated doses of vermicompost, neem manure, farmyard manure, phosphorus, potassium and half of nitrogen were applied as basal dose through single super phosphate, muriate of potash and calcium ammonium nitrate respectively as per treatment combination in the individual specified plots before transplanting of the seedlings by broadcasting method and were thoroughly mixed with the surface layer of soil. The remaining dose of nitrogen in the form of calcium ammonium nitrate as per the treatments was side-dressed after five weeks of transplanting. The biofertilizers (*Azotobacter* and PSB) were applied through seedlings dip method for 30 minutes before transplanting. One month old healthy seedlings were transplanted in already prepared raised beds at a spacing of 60 x 45 cm during evening hours in the second week of October 2011 and 2012. Only organic-based formulations like botanical spray (5%) locally prepared and neem-based formulations like Neemajal (2%) and Achook (0.15%) were used to manage the biotic stresses. In general 5 sprays of each formulation in alternate manner were applied. Randomly five plants from each plot were selected for recording observations. Disease rating was done according to William et al (1972) and per cent disease severity was calculated by using formula given by McKinney (1923). Available N, P and K nutrient contents were analysed as per standard methods of estimation of Subbiah and Asija (1956), Olsen et al (1954) and Merwin and Peech (1951) respectively. The analysis of variance of data was done as per design of the experiment as suggested by Panse and Sukhatme (1987).

RESULTS and DISCUSSION

The data on the effect of various treatments are given in Table 3a and 3b.

Head yield per hectare

Perusal of data reveals considerable variability in yield level. Variable level of yield per plot and per hectare was recorded with respect to different combinations of organic, inorganic and biofertilizers. The combination of biofertilizers with inorganic fertilizer produced maximum yield per plot and per hectare followed by application of organic manures like farmyard manure, vermicompost, *Azotobacter* and PSB with reduced level of NPK. This may be because of appropriate level of nitrogen which acts as an integral component of many compounds including chlorophyll and enzymes that are critical for carbohydrate use within plants. Further phosphorus being a part of ADP and ATP also plays an important role in the uptake of nutrients. Similarly potassium activates various enzymes, modifies energy metabolism, supports starch synthesis, photosynthesis, sugar translocation and ultimately plant growth in broccoli. Application of NPK in conjunction with biofertilizers might have favoured the effective utilization of nutrients available in the soil which ultimately increased auxin activities, growth and activity of microbial saprophytes which influenced the yield per hectare. The present findings are in agreement with the results of Singh and Singh (2000), Sharma (2000) and Sharma et al (2008).

Days taken to 50 per cent heading

Days taken to 50 per cent heading is an important attribute in order to determe earliness of crop. In the present studies sole application of biofertilizers and different organic manures took minimum days for 50 per cent heading. This may be due to the lesser availability of available nitrogen throughout the growing season and early conversion of vegetative stage to reproductive stage (Jana and Mukhopadhyay 2001). On the other hand treatment T_{21} ie 33.3 per cent of RDF + FYM (33.3%) + vermicompost (33.3%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg) took maximum days for 50 per cent heading. Data also reveal that the combination of different organic, inorganic, biofertilizers and reduced levels of recommended dose

of fertilizers took more days to 50 per cent heading than sole application of different manures and biofertilizers. This may be because of the active role of NPK in crop maturation as increased availability of NPK resulted in better crop growth which may have ultimately delayed the formation of head (Kumar et al 2012). Yadav et al (2012) have also reported that application of nitrogen and biofertilizers increased the availability of available soil nitrogen content at the later stages which ultimately favoured more uptake of nutrients and increased the vegetative growth thereby took more days to head formation.

Plant height at maturity

The different treatment combinations showed significant variation with respect to plant height. Maximum plant height was attained with the application of recommended dose of fertilizer (33.3%) + FYM (33.3%) + vermicompost (33.3%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha) ie treatment T_{21}. This may be attributed to better water holding capacity, supply of micronutrients and availability of major nutrients due to favourable soil conditions offered by the farmyard manure and vermicompost (Choudhary et al 2012). Bhardwaj et al (2007) also stated that application of biofertilizers helps in secretion of growth promoting substances which leads to better root development, transportation of water and uptake and decomposition of nutrients. On the other hand individual application of organic manures and biofertilizers recorded the least plant height.

Number of leaves per plant

The treatment combination (T_{21}) of organic (FYM 33.3% and vermicompost 33.3%), biofertilizers (*Azotobacrter* 5.0 kg/ha and PSB 5.0 kg/ha) and application of nutrients with reduced level of inorganic fertilizers (NPK 33.3%) produced highest number of leaves per plant. Present studies clearly indicate that vermicompost in combination with farmyard manure played a significant role in enhancing the growth and ultimately number of leaves in broccoli. Improvement in this growth attribute with the application of vermicompost might be due to more availability of water, micronutrients and major nutrients because of favourable soil condition (Choudhary et al 2012). The growth promoting substances secreted by microbes and increased availability of atmospheric nitrogen due to fixation by *Azotobacterium* (Akbar et al 2009) helped in more plant growth. According to Yadav et al (2012) the increase in number of leaves per plant due to the application of nitrogen, phosphorus and potassium in combination with biofertilizers might have increased the availability of nutrients through direct addition in the soil.

Severity of black rot

Black rot of sprouting broccoli is a bacterial disease which is caused by *Xanthomonas campestris* pv *campestris*. The development of disease is favoured by warm and humid climate. Therefore the severity of this disease at the head production stage is less. Verma (2001) has reported that disease severity increased with increase in relative humidity at all temperatures while the increase in disease severity with increase in temperature was recorded up to 30°C. Disease is considered soil as well as seed borne. In the present studies higher disease severity was reported in those plots where only farmyard manure was applied whereas lower severity was recorded in those plots which received organic manures like vermicompost, neem manure and biofertilizers (*Azotobacter* and phosphate solubilizing bacteria) with reduced level of NPK. This may be due to active and rapid multiplication of bacteria especially in rhizosphere which creates favourable conditions for N-fixation at higher rate and availability of insoluble nutrients, hormone secretion and supply of antibacterial and antifungal compounds.

Similar findings have also been reported by Goel et al (2003) who were of the opinion that heavy or lesser dose of nitrogen reduced hemicelluloses and lignin in cell wall and weakened the mechanical resistance of the plant to the pathogen. Same results have also been reported by Khan et al (2010) in cauliflower. Therefore balanced nutrition through integrated nutrient management is important for reduction in black rot severity in sprouting broccoli.

Available nitrogen

Available nitrogen after harvest of the crop was highest under treatment T_{21}. The increase in available N might be due to direct addition of N through vermicompost and farmyard manure. Application of biofertilizers leads to multiplication of soil microbes which are capable to convert organically bound N into inorganic form (Sharma et al 2008). Sarangthem et al (2011) opined that addition of biofertilizers along with organic sources narrowed the C:N ratio of the organic manures and thus enhanced the rate of mineralization resulting in rapid release of nutrient from the organic

Table 1. Physico-chemical properties of soil before experimentation

Soil pH (1:2.5)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
6.70	0.98	225.00	27.00	150.00

Table 2. Details of treatments used in the experiment

T	Components
T_1	FYM (20.0 tons/ha)
T_2	VC (5.0 tons/ha)
T_3	NM (2.0 tons/ha)
T_4	*Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_5	FYM (75%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_6	VC (75%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_7	NM (75%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_8	FYM (50%) + VC (50%)
T_9	FYM (50%) + NM (50%)
T_{10}	VC (50%) + NM (50%)
T_{11}	FYM (37.5%) + VC (37.5%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{12}	FYM (37.5%) + NM (37.5%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{13}	VC (37.5%) + NM (37.5%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{14}	FYM (33.3%) + VC (33.3%) + NM (33.3%)
T_{15}	FYM (25%) + VC (25%) + NM (25%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{16}	RDF + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{17}	RDF (75%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{18}	RDF (50%) + FYM (25%) + VC (25%)
T_{19}	RDF (50%) + FYM (25%) + NM (25%)
T_{20}	RDF (50%) + VC (25%) + NM (25%)
T_{21}	RDF (33.3%) + FYM (33.3%) + VC (33.3%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{23}	RDF (33.3%) + FYM (33.3%) + NM (33.3%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{24}	RDF (25%) + VC (25%) + NM (25%) + FYM (25%) + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha)
T_{25}	Control (RDF, FYM 20 tons/ha, CAN:SSP:MoP 500:475:85 kg/ha)

T= treatment, FYM= Farmyard manure, NM= Neem manure, PSB= Phosphorus solublising bacteria, VC= Vermicompost, RDF= Recommended dose of fertilizer

sources. The present findings are in line with the findings of Dass et al (2008) in cauliflower and Yoldas et al (2008) in broccoli.

Available phosphorus

During both the years of study available phosphorus was observed to be highest in treatment T_{21}. The higher available phosphorus might be due to the application of vermicompost along with biofertilizers which resulted into reduction in fixation of water soluble phosphorus, increased mineralization of organic phosphorus due to microbial action and enhanced mobility of phosphorus (Sarangthem et al 2011). Dass et al (2008) have the opinion that overall increase in the available phosphorus of soil could be due to addition of organic matter, NPK and increased population of microbes that can convert bound P to available form. Another possible reason may be due to the decomposition of organic matter and P solubilization from the native soil pool. The organic materials form a

Table 3a. Effect of organic and inorganic fertilizers on head yield per hectare and growth attributes of sprouting broccoli cv Green Head

Treatment	Head yield (q/ha)			Days taken to 50% heading			Plant height (cm)			Number of leaves		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
T_1	79.54	79.99	79.76	85.67	88.00	86.83	34.22	33.58	33.90	15.38	14.90	15.14
T_2	79.82	81.65	80.74	89.00	89.33	89.17	35.11	34.33	34.72	15.27	15.65	15.46
T_3	73.08	71.29	72.18	86.33	84.00	85.17	34.00	33.67	33.83	14.39	15.65	15.02
T_4	65.54	61.72	63.63	83.67	83.00	83.33	33.44	32.67	33.05	14.17	14.65	14.41
T_5	92.50	83.01	87.76	88.00	85.00	86.50	37.78	35.00	36.39	16.94	15.98	16.46
T_6	84.72	104.03	94.38	87.00	84.67	85.83	35.55	35.00	35.28	15.83	16.98	16.41
T_7	85.53	99.50	92.52	88.67	88.67	88.67	35.66	37.33	36.50	16.39	19.31	17.85
T_8	91.16	84.98	88.07	89.67	90.33	90.00	36.55	35.00	35.78	16.83	16.98	16.9
T_9	100.41	112.66	106.53	85.67	88.33	87.00	38.55	35.33	36.94	17.61	15.64	16.63
T_{10}	96.82	106.97	101.89	89.67	89.67	89.67	37.50	36.33	36.92	18.27	18.31	18.29
T_{11}	95.10	111.77	103.43	91.67	91.33	91.50	36.00	34.67	35.33	17.72	16.65	17.18
T_{12}	97.15	88.80	92.98	88.33	90.00	89.17	36.22	35.50	35.86	17.05	17.48	17.27
T_{13}	101.64	120.09	110.86	88.00	86.33	87.17	38.55	34.67	36.61	16.61	16.65	16.63
T_{14}	99.69	113.14	106.41	84.00	87.67	85.83	38.33	36.50	37.42	19.16	18.48	18.82
T_{15}	92.20	116.45	104.33	88.00	84.67	86.33	36.22	35.67	35.94	16.39	15.65	16.02
T_{16}	151.83	150.69	151.26	91.00	91.33	91.17	42.67	39.67	41.17	19.83	21.65	20.74
T_{17}	135.03	118.41	126.72	92.00	92.67	92.33	41.33	37.78	39.55	17.50	21.09	19.29
T_{18}	120.84	104.81	112.82	87.00	92.33	89.67	40.00	37.00	38.50	17.27	18.98	18.13
T_{19}	123.89	104.23	114.06	90.00	87.00	88.50	36.22	37.83	37.03	17.94	17.81	17.88
T_{20}	127.62	125.53	126.57	86.33	84.67	85.50	38.77	39.11	38.94	18.61	19.42	19.02
T_{21}	143.46	141.39	142.43	94.33	95.00	94.67	44.78	40.83	42.81	21.14	22.81	21.98
T_{22}	130.84	134.70	132.77	90.33	90.33	90.33	43.22	37.11	40.17	20.02	18.09	19.06
T_{23}	135.33	121.04	128.18	91.00	90.33	90.67	42.78	39.66	41.22	19.91	21.64	20.78
T_{24}	139.32	117.33	128.33	89.00	87.00	88.00	42.78	39.78	41.28	19.25	21.76	20.50
T_{25}	147.34	144.09	145.72	90.67	91.33	91.00	40.55	39.83	40.19	19.25	20.81	20.03
Mean	107.62	107.93	107.77	88.60	88.52	88.56	38.27	36.55	37.41	17.55	18.12	17.84

$CD_{0.05}$

	Y	T	Y x T
Head yield	NS	21.02	NS
Days taken to 50% heading	NS	3.67	NS
Plant height	0.86	3.50	NS
Number of leaves	NS	2.15	NS

Table 3b. Effect of organic and inorganic fertilizers on severity of black rot and soil fertility status of sprouting broccoli cv Green Head

Treatment	Severity of black rot (%)			Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
T_1	29.88 (5.46	29.91 (5.46)	29.89 (5.46)	251.50	270.67	261.08	41.67	36.33	39.00	187.83	195.58	191.71
T_2	28.45 (5.33)	29.53 (5.43)	28.99 (5.38)	254.67	279.00	266.83	42.00	37.67	39.83	186.50	190.58	188.54
T_3	28.23 (5.31)	29.81 (5.46)	29.02 (5.39)	242.17	254.00	248.08	36.33	32.00	34.17	174.83	175.58	175.21
T_4	28.01 (5.29)	28.99 (5.38)	28.50 (5.34)	261.50	290.67	276.08	42.67	38.00	40.33	168.17	165.58	166.88
T_5	28.11 (5.30)	28.75 (5.36)	28.43 (5.33)	270.08	297.17	283.63	49.67	47.33	48.50	191.50	195.58	193.54
T_6	27.67 (5.26)	28.87 (5.37)	28.27 (5.32)	340.25	319.25	329.75	52.17	49.17	50.67	191.33	192.08	191.71
T_7	27.56 (5.25)	28.18 (5.30)	27.87 (5.28)	276.50	302.17	289.33	46.00	46.33	46.17	193.50	194.25	193.88
T_8	27.99 (5.29)	28.15 (5.30)	28.07 (5.30)	313.83	311.17	312.50	46.67	47.00	46.83	203.00	203.75	203.38
T_9	26.68 (5.16)	27.80 (5.27)	27.24 (5.22)	289.00	302.00	295.50	45.00	45.33	45.17	201.67	202.42	202.04
T_{10}	27.23 (5.22)	28.43 (5.33)	27.83 (5.27)	313.83	311.17	312.50	45.00	46.67	45.83	208.00	208.75	208.38
T_{11}	26.77 (5.17)	28.81 (5.36)	27.79 (5.27)	289.04	303.04	296.04	54.17	50.17	52.17	220.00	220.75	220.38
T_{12}	26.21 (5.12)	26.79 (5.17)	26.50 (5.15)	324.00	302.83	313.42	42.92	43.25	43.08	213.40	214.15	213.78
T_{13}	25.84 (5.08)	27.13 (5.21)	26.49 (5.14)	285.70	310.04	297.87	46.25	49.92	48.08	201.75	202.50	202.13
T_{14}	24.78 (4.97)	27.80 (5.27)	25.24 (5.12)	292.70	313.70	303.20	46.63	46.96	46.79	230.33	231.08	230.71
T_{15}	22.92 (4.79)	28.77 (5.36)	25.84 (5.08)	289.00	301.08	295.04	46.67	50.33	48.50	212.33	213.08	212.71
T_{16}	23.96 (4.89)	26.38 (5.13)	25.17 (5.01)	342.83	340.50	341.67	65.33	62.67	64.00	218.75	219.50	219.13
T_{17}	25.22 (5.02)	28.72 (5.36)	26.97 (5.19)	288.04	305.70	296.87	64.00	62.00	63.00	201.08	209.25	205.17
T_{18}	23.52 (4.85)	27.92 (5.28)	25.72 (5.07)	316.17	313.83	315.00	56.33	51.33	53.83	228.42	226.58	227.50
T_{19}	23.66 (4.86)	28.51 (5.34)	26.09 (5.10)	311.58	301.58	306.58	53.00	51.33	52.17	229.75	227.92	228.83
T_{20}	24.08 (4.91)	28.19 (5.30)	26.13 (5.10)	316.17	306.17	311.17	55.50	57.17	56.33	218.75	216.92	217.83
T_{21}	22.63 (4.76)	23.22 (4.82)	22.93 (4.79)	364.84	354.84	359.84	68.60	65.01	66.81	239.23	235.07	237.15
T_{22}	23.44 (4.84)	24.41 (4.94)	23.93 (4.89)	333.22	326.55	329.88	66.19	64.61	65.40	224.23	222.40	223.32
T_{23}	23.38 (4.83)	25.51 (5.05)	24.44 (4.94)	358.21	348.21	353.21	65.86	65.28	65.57	221.57	219.73	220.65
T_{24}	23.00 (4.80)	25.82 (5.08)	24.41 (4.94)	352.87	342.87	347.87	66.58	60.67	63.63	236.23	234.40	235.32
T_{25}	23.00(4.80)	26.51 (5.15)	24.71 (4.97)	318.50	308.50	313.50	65.58	64.00	64.79	215.90	214.07	214.98
Mean	25.69 (5.06)	27.72 (5.26)	27.62 (5.16)	303.85	308.67	306.26	52.43	50.82	51.63	208.72	209.26	208.99

Square root transformed values in parentheses

$CD_{0.05}$	Y	T	Y x T
Severity of black rot	0.50	0.18	NS
Available N	NS	25.98	NS
Available P	1.38	4.87	NS
Available K	NS	17.73	NS

cover on sesquioxides and reduce phosphate fixing capacity of soil (Sharma et al 2008). Minimum available phosphorus was observed with sole application of neem manure.

Available potassium

Available potassium content in soil was found to be highest in treatment combination T_{21} closely followed by the treatment 100 per cent recommended dose of NPK + *Azotobacter* (5.0 kg/ha) + PSB (5.0 kg/ha). The increase in available potassium with integrated application of biofertilizers with organic source (vermicompost and FYM) might be due to the beneficial effect of organic source and bioresource (Sarangthem et al 2011). The increase in available potassium with the incorporation of organics in combination with inorganic source was similar as with the findings of Dass et al (2008) and Bhardwaj et al (2012). Another possible reason in improvement of potassium status in soil is ascribed to the reduction of fixation and release of K due to the interaction of organic material with clay. Similar results have also been reported by Sood and Sharma (2002) in sprouting broccoli.

CONCLUSION

From the present studies it can be concluded that balanced integration of nutrients viz organic manures and biofertilizers with reduced dose of inorganic fertilizers sustain yield potential as well as maintain the soil health and fertility with minimum severity of black rot.

REFERENCES

Akbar PI, Kumar V and Malik MF 2009. Effect of bio-organic fertilizers on the performance of cabbage under western UP conditions. Annals of Horticulture **2(2):** 204-206.

Bhardwaj AK, Kumar P and Singh RK 2007. Response of nitrogen and pre-planting treatment of seedlings with the *Azotobacter* on growth and productivity of broccoli (*Brassica oleracea* var *italica*). Asian Journal of Horticulture **2(1):** 15-17.

Bhardwaj SK, Sharma SD and Kumar P 2012. Effect of conjoint use of bio-organics and chemical fertilizers on yield, soil properties under French bean-cauliflower-based cropping system. Archives of Agronomy and Soil Science **58(7):** 759-763.

Choudhary S, Soni AK and Jat NK 2012. Effect of organic and inorganic sources of nutrients on growth, yield and quality of sprouting broccoli cv CBH-1. Indian Journal of Horticulture **69(4):** 550-554.

Dass A, Lenka NK, Patnaik US and Sudhishri S 2008. Integarted nutrient management for production, economics and soil improvement in winter vegetables. International Journal of Vegetable Science **14(2):** 104-120.

Goel RK, Rekhi RS and Singh S and Parminder K 2003. Integrated nutrient management in relation to the occurance of some major diseases and grain yield in rice. Plant Disease Research, PAU **18(1):** 34-36.

Jana JC and Mukhopadhyay TP 2001. Effect of nitrogen and phosphorus on growth and curd yield of cauliflower var Aghani in Terai zones of West Bengal. Vegetable Science **28(2):** 133-136.

Khan N, Singh SK, Srivastava JP and Siddiqui MZ 2010. Effect of bio-fertilizers on production potential and economic feasibility of cauliflower (*Brassica oleracea* L var *botrytis*). Progressive Agriculture **10(2):** 371-373.

Kumar M, Kumari P, Ojha RK, Kumar A and Prasad KK 2012. Effect of temperature on growth and yield of broccoli under integrated nutrient management. Progressive Horticulture **44(2):** 307-312.

McKinney HH 1923. Influence of soil temperature and moisture on infection of wheat seedlings by *Helminthosporium sativus*. Journal of Agricultural Research **26:** 195-218.

Merwin HD and Peech M 1951. Exchangeability of soil potassium in the sand, silt and clay fractions as influenced by the nature of the complimentary exchangeable cations. Proceedings, Soil Science Society of America **15(2):** 125-128.

Olsen SR 1954. Estimation of available posphorous in soils by extraction with sodium bicarbonate. USDA, Washington, DC, Circular # 939, pp 1-19.

Panse V and Sukhatme P 1987. Statistical methods for agricultural workers. ICAR, New Delhi, India.

Sarangthem I, Misra ADD and Chakraborty Y 2011. Cabbage productivity, nutrient uptake and soil fertility as affected by organic and bio-sources. Agricultural Science Digest **31(4):** 260-264.

Sharma A, Parmar DK, Kumar P, Singh Y and Sharma RP 2008. *Azotobacter* soil amendment integrated with cow manure reduces need for NPK fertilizers in sprouting broccoli. International Journal of Vegetable Science **14(3):** 273-285.

Sharma KC 2000. Influence of integrated nutrient management on yield and economics in broccoli (*Brassica oleracea* L var *italica* Plenck) cv Green Head

under cold temperate conditions. Vegetable Science **27(1):** 62-63.

Singh AK and Singh A 2000. Influence of nitrogen and potassium on growth and head yield of broccoli (*Brassica oleracea* L var *italic* L Plenck) under low hills subtropical condition of HP. Vegetable Science **27(1):** 99-100.

Sood S and Sharma JJ 2002. Production potential and economic returns of different harvest management systems in broccoli (*Brassica oleracea* L var *italica* Plenck) under temperate conditions. Vegetable Science **29(1):** 43-44.

Subbiah BV and Asija GL 1956. A rapid procedure for the estimation of available nitrogen in soils. Current Science **25:** 259-260.

Thamburaj S and Singh N 2001. Vegetables, tubercrops and spices. Directorate of Information and Publications of Agriculture, Indian Council of Agricultural Research, New Delhi, India, 469p.

Verma K 2001. Studies on black rot of cauliflower caused by *Xanthomonas campestris* pv *campestris* (PAM) Downson. PhD thesis. Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India.

William PH, Staub T and Sutton JC 1972. Inheritance of resistance in cabbage to black rot. Phytopathology **62:** 247-252.

Yadav LP, Kavita A and Maurya IB 2012. Effect of nitrogen and biofertilizers on growth of cabbage (*Brassica oleracea* var *capitata* L) var Pride of India. Progressive Horticulture **44(2):** 318-320.

Yoldas F, Ceylan S, Yagmur B and Mordogan N 2008. Effect of nitrogen fertilizer on yield, quality and nutrient content in broccoli. Journal of Plant Nutrition **31(7):** 1333-1343.