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Integrated Nutrient Management Strategies to Improve Yield and Quality of Strawberry Fruits

S. K. Yadav[1], U. U. Khokar[1], and Fozia Homa[3]*

[1]ICAR-Indian Institute of Soil and Water Conservation Research Centre, Datia-475661 (Madhya Pranesh)
[2] Department of Pomology, Dr. Y.S. Parmar University of Horticulture & Forestry, Nauni, Solan-173 230 (H.P.) India
[3] Department of Statistics, Mathematics, and Computer Application, Bihar Agricultural University, Sabour, Bhagalpur-813210, Bihar, India.

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Abstract

People all over the world prefer strawberry for its attractive colour, pleasant flavour, and richness in vitamins and minerals. Berries are highly perishable and mainly used for the table purpose. Hence, quality attributes play very important role in determining economic viability of its commercial cultivation. A field study was conducted in Himachal Pradesh (India) to standardize integrated nutrient management (INM) strategy through suitable combination of various organic, inorganic and biological nutrient sources to achieve higher productivity of quality berries. Total recommended doses of organic and inorganic fertilizers (50 t ha^{-1} farmyard manure and 80, 40, 40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively) were converted in terms N, P and K. The nutrient requirements were supplied through different combinations of organic and inorganic sources (50% organic and 50% inorganic or 100% inorganic) with and without *Azotobacter* inoculation. Inorganic nitrogen was applied at one or two at the stages of establishment of plant and before flowering. Application of 50% nitrogen through vermicompost along with *Azotobacter* inoculation and remaining 50% nitrogen through inorganic source in two splits produced maximum number of flowers and berries per plant, marketable fruit yield, production 'Extra class' and 'Class-I' grade berries with best fruit quality attributes.

Keywords
Vermicompost
Azotobacter
Integrated nutrient management (INM)
Fruit quality
Fruit grades

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most popular soft fruit of the world which can be successfully cultivated from subtropical to temperate climate i.e. up to 3000 meter above mean sea level. People all over the world prefer it due to attractive colour, pleasant flavour, and rich source of vitamin C, B_1, B_2, Niacin and the minerals like phosphorus, potassium, calcium and iron. Berries are highly perishable and mainly used for the table purpose. Hence the quality attributes of its fruit like size, TSS, sugars, acidity and anthocyanin pigmentation plays very important role in marketing of produce.

In India, strawberry cultivation becomes popular in the late 60's of twentieth century and presently covers significant area in the states of Himachal Pradesh, Uttarakhand, Maharashtra, Jammu and Kashmir and hills of Darjiling and Nilgiris.

Strawberry is a herbaceous perennial with shallow adventitious roots system, of which 50-90 per cent is confined to upper 15 cm of the soil profile and very sensitive to nutrient and soil moisture fluctuations (Galletta and Bringhurst, 1990). Regular supplements of organic manure help in sustaining productivity of high quality fruits through its ability to maintain consistent supply of ideal nutrient solution

**Corresponding author* (Email: fozia.homa.bhu@gmail.com)

to the root rhizosphere under optimum physico-chemical environment. Therefore, a balanced and integrated supply of various nutrient supplements is of great relevance in commercial cultivation of strawberry.

Vermicompost is gaining popularity and preference over farmyard manure as former is a richer source of available plant nutrients, growth regulators, enzymes, antifungal and antibacterial compounds (Arancon *et al.*, 2004). *Azotobacter* a free living nitrogen fixing bacteria is also known to synthesize biologically active growth promoting substances such as IAA, GA *etc*., apart from having ability to fix atmospheric nitrogen into the soil profile. Its inoculation has great potential to supplement nutritional requirements of the non-leguminous fruit crops (Pathak *et al.*, 2003). Integrating *Azotobacter* with inorganic fertilizers and GA_3 caused significant improvement in fruit yield of strawberry (Singh and Singh, 2009). Commercial availability of vermicompost and *Azotobacter* inoculants has paved the way for their use in commercial fruit production. The present investigations on strawberry cv. Chandler were carried out to standardize integrated nutrient supply system through combination of organic, inorganic and biological sources, to obtain higher productivity and excellent quality of strawberry fruits.

MATERIALS AND METHODS

Materials and treatments

Field studies to evolve a suitable integrated nutrient supply system for strawberry were conducted at experimental orchard of Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) located at 30^0 50' 45"N latitude and 77^0 08' 30"E longitude about 1240 meter above mean sea level. The soils are sandy clay loam texture and are neutral in reaction (pH 6.8). These are medium in availability of N (407.7 kg ha^{-1}) and K_2O (166.6 kg ha^{-1}) and high in P_2O_5 (46.2 kg ha^{-1}) and organic carbon (1.8%).

Raised beds of dimension 1 m x 1.25 m at spacing of 25 cm x 50 cm were constructed for planting of uniform size runners. A 50 cm wide channel between two beds was provided for irrigation as well as passage for intercultural operations. Uniform size runners of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler 10 plants per bed (53,333 plants ha^{-1}) were transplanted in the month of September, 2004. Strawberry crop is fertilized with 50 tonnes of farmyard manure and 80, 40 and 40 kg ha^{-1} of N, P and K, respectively from inorganic sources (Verma *et al.,* 2003). The total recommended dose of organic manure and inorganic fertilizers was converted into the form of N, P and K nutrients and then the cumulative doses were applied in various combinations of organic manures (Farmyard manure: 0.5% N, 0.2% P_2O_5 and 0.5% K_2O; Vermicompost: 1.0% N, 0.7% P_2O_5 and 0.8% K_2O) and inorganic fertilizers with or without *Azotobacter* inoculation. Inorganic fertilizers used were calcium ammonium nitrate, single super phosphate and muriate of potash for supply of N, P and K, respectively.

The experiment was laid out in a randomized block design with 13 treatments and replicated thrice. The treatments comprised of **T_1** - Recommended doses of manures and fertilizers- inorganic N in two equal split at establishment and before flowering stage (Control), **T_2** - ½ N as basal and remaining ½ N before flowering, all through inorganic source (Inorganic Fertilizer), **T_3 -** ½ N through of FYM and remaining ½ N before flowering through inorganic source (INM with FYM and inorganic N in one split), **T_4 -** ½ N through vermicompost and remaining ½ N before flowering through inorganic source (INM with vermicompost and inorganic N in one split), **T_5 -** ½ N through FYM and remaining ½ N in two equal split doses, each at establishment and before flowering through inorganic source (INM with FYM and inorganic N in two split), **T_6** - ½ N through vermicompost and remaining ½ N through inorganic source in two equal split doses, each at establishment and before flowering (INM with vermicompost and inorganic N in two split), **T_7** - *Azotobacter* inoculation, without any manure and fertilizer, **T_8** - T_2 + *Azotobacter* inoculation, **T_9** - T_3 + *Azotobacter* inoculation, **T_{10}** - T_4 + *Azotobacter* inoculation, **T_{11}** - T_5 + *Azotobacter* inoculation, **T_{12}** - T_6 + *Azotobacter* inoculation, **T_{13}** - No manure, fertilizer or *Azotobacter* inoculation.

Organic manures, phosphorus and potassium were applied basal at the time of final preparation of the beds in all the treatments as per the requirement to supply required nutrients. Nitrogenous fertilizers were applied at the stages of establishment of plant and before flowering according to the treatment plan. *Azotobacter* culture was inoculated at the rate of 2.0 kg ha^{-1} by dipping runner roots in culture slurry at the time of transplanting. Other cultural practices like weeding, mulching, hoeing, irrigation, insect pest and disease management were as per standard practices and common for all the treatments.

Methods

Observations in respect of number of berries and number of flowers per plant were recorded by counting their respective numbers in 5 randomly selected plants. Duration of flowering is the period between emergences of flowers in 10 percent plant and ceasing of flowering in 80 percent plants while, duration of harvesting is the period between first harvesting of fruits in 10 percent plant and ceasing of harvesting in 80 percent plants of the treatments. Weight of berry was recorded by averaging weights of randomly selected 20 berries from each treatment. Total marketable berries produced per plot were graded as per UNECE Standard (FFV-35), weighed and expressed as yield in kg ha^{-1}. Standard methods were used to determine total soluble solids (refrectometer), titratable acidity (0.1N NaOH and Phenolphthalein indicator), sugars -total and reducing (Fehling A, B and methyl blue indicator), ascorbic acid (2,6-dichlorophenol indophenol dye) and phenol (Bray and Thorpe,1955) contents in fruits. Anthocyanin pigmentation was recorded by using horticultural colour chart of Royal Horticultural Society, London.

Data recorded from the present investigations were analysed statistically, employing Randomized Block Design and least squire differences at 5% level of significance. Mean values were taken to compare the treatment effects and to interpret the differences.

RESULTS AND DISCUSSION

The effect of various treatment combinations was studied on number of flower and berries per plant, percent berry set, weight and density of berry, duration of flowering and harvesting, grade wise production of marketable fruits, and fruit quality attributes like total soluble solids (TSS), total sugars, reducing sugars, ascorbic acid, total phenols, titratable acidity and TSS/Acid ratio. The results obtained are discussed in sub heads below.

Table-1: Effect of various nutrient treatments on the reproductive parameters of strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler.

Treatments		Number of flowers/ plant	Percent berry set	No. of berries per plant	Duration of Flowering (days)	Yield (Kg/ha)	Duration of Harvesting (days)
Recommended doses of manures and fertilizers- full dose of FYM, P and K as basal + inorganic N in two equal split at establishment and before flowering stage	(T_1)	28.60	70.34	20.13	129.00	9369.53	65.67
½ N, full P and K as basal and remaining ½ N before flowering, all through inorganic source	(T_2)	22.83	65.25	14.90	132.00	6494.31	55.33
½ N through of FYM + full P and K as basal and remaining and ½ N through inorganic source before flowering	(T_3)	25.47	73.50	18.67	124.33	7545.18	63.67
½ N through Vermicompost + full P and K as basal dose remaining ½ N through inorganic source before flowering	(T_4)	26.63	73.54	19.63	134.00	8319.56	61.67
½ N through FYM, full P and K at planting + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_5)	28.43	75.25	21.40	134.33	9792.54	66.00
½ N through vermicompost + full P and K as basal + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_6)	28.87	76.23	22.07	133.33	9830.41	71.67
Azotobacter inoculation, without any manure and fertilizer, @ 2 kg/ha at the time of planting	(T_7)	21.47	62.57	13.43	125.00	4698.87	61.67
T_2 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_8)	24.87	61.66	15.33	136.00	6494.13	59.67
T_3 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_9)	26.40	71.90	18.97	134.00	7951.80	62.67
T_4 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{10})	25.13	75.17	18.90	129.33	8713.14	61.00
T_5 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{11})	27.93	75.84	21.23	138.00	9948.43	67.67
T_6 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{12})	29.60	75.23	22.27	142.33	10199.40	67.33
Control (No manure, fertilizer or Azotobacter inoculation)	(T_{13})	15.20	57.18	8.73	124.33	3709.62	49.67
$CD_{0.05}$		4.14	3.73	3.41	NS	1191.05	7.75

Flowering and fruit set

Effect of integrated nutrient management strategies were studied on reproductive growth parameters of berry like number of flowers, number of berries, percent berry set, duration of flowering, and duration of harvesting were recorded to study the (Table1). Majority of INM treatments receiving 50% N through organic manures from different source, splitting of inorganic N and *Azotobacter* inoculation produced higher number of flowers and fruits per plant. However, INM treatment receiving 50% N through vermicompost (T_{12}) had maximum number of flowers and berries (29.6 and 22.3 per plant). The sources of organic manures caused non-significant differences on flowering and fruit setting. Unfertilized treatment (T_{13}) recorded least number of flowers and berries and integrated nutrient management combinations receiving 50% nitrogen through organic sources (farmyard manure and vermicompost), splitting of inorganic dose of nitrogen and *Azotobacter* inoculation has potential to enhance these parameters in the range of 67.8% to 94.7% and 117.2% to 156.3% respectively over it. Ali *et al.* (2003) also reported higher number of flowers, more fruits set and high fruit retention with combined application of nitrogen, phosphorus and farmyard manure in strawberry. Integrated nutrient management did influence the berry setting and duration of harvesting. The INM treatment receiving vermicompost and inorganic N in two splits without *Azotobacter* inoculation (T_6) recorded highest percentage of berry set (76.5%) and extended duration of harvesting (71.67 days). Majority of INM treatment having combination of organic and inorganic sources of nutrition irrespective of splitting of inorganic N and *Azotobacter* inoculation has at par percent berry set However, splitting of inorganic N in INM treatments (T_1, T_5, T_6, T_{11} and T_{12}) has significantly longer extended duration of harvesting.

Organic manures (vermicompost and farmyard manure) have favourable impact on flowering and fruit set is due to their capability of producing growth hormones, enzymes, antifungal and antibacterial compounds, besides consistent release of plant nutrients. Similarly *Azotobacter* beneficial role was due to its involvement in the fixation of atmospheric nitrogen.

Fruit Yield

INM treatment with 50% N through vermicompost with *Azotobacter* inoculation and inorganic N in two splits (T_{12}) produced maximum marketable berries was (10199.4 kg ha^{-1}). The yield saw an improvement of 8.9% and 174.9% higher over the recommended package of practices (T_1) and unfertilized treatment (T_{13}), respectively (Table 2). Splitting of inorganic N in two doses for application (T_1, T_5, T_6 and T_{11}) proved equally effective in berry fruit production irrespective of source of organic manures and *Azotobacter* inoculation. Correlation analysis of different parameters reveals that enhancement in production of marketable berries is combined cumulative effect of the higher number of flowers (r=0.94), higher number of berries (r=0.98) and higher percent berry set (r=0.92). Maximum production of 'Extra Class' (2739.9 kg ha^{-1}) and 'Class-I' berries (4993.4 kg ha^{-1}) was also recorded in treatment T_{12} and also follows the same trend of significance as in case of production of marketable berries. However, production of 'Class-II' berries was at par in all the INM treatments irrespective of source of organic manures, splitting of inorganic N and *Azotobacter* inoculation. The above observations reveal that application of inorganic nitrogen in split dose has potential to improve reproductive growth and fruit yield of the strawberry plants. The findings of Kapanski and Kawecki (1994), Wang and Lin (2002), Turemis (2002) and Ali *et al.* (2003) also rewealeded that integration of organic manures and inorganic fertilizers with split application inorganic nitrogen resulted in highest fruit yield in different regions.

Fruit quality

Effect of different nutrient treatments on various fruit quality attributes *viz.* weight and density of berries, total soluble solids (TSS), titratable acidity, TSS/Acid ratio, total sugar, reducing sugar, ascorbic acid, total phenols and anthocyanin pigmentation (Tables 1 and 3) were recorded. Different nutrient combinations affected significant differences in all the above parameters except weight of berry and total phenol. The treatments receiving complete nutrition through inorganic sources only with and without *Azotobacter* inoculation (T_2 and T_8), significantly reduced fruit density. The reduction in fruit density is due to the formation of hollow pith in berries of these treatments. The INM treatments receiving 50% N through vermicompost with *Azotobacter* inoculation and remaining 50% N through inorganic sources in two splits (T_{12}) has highest concentration of total soluble solids (12.20^0 Brix) in the berry fruits that is 41.9% more than minimum recorded in 100% inorganic treatment with *Azotobacter* inoculation and top dressing of N in one split (T_8). However, treatments receiving 100% inorganic N but top dressing of N in two splits (T_6, T_{11}) produced fruit with at par total soluble sugars with T_{12}. The T_{12} treatment also has highest values of TSS/acid ration (14.02) that is 50.0% more than minimum observed in 100% inorganic treatment with one split and without *Azotobacter* inoculation(T_2). The INM treatment through farmyard manure with *Azotobacter* inoculation and inorganic N in two splits (T_{11}) was equally effective. These findings reveal that integrated nutrient management strategy comprising 50% nitrogen through either organic manure and remaining 50% through inorganic fertilizer in two splits irrespective of *Azotobacter* inoculation have potential to enhance TSS and TSS/Acid ratio over inorganic nutrition alone. The findings of Ali *et al.* (2003) also revealed that combined application of NPK and FYM significantly enhanced the TSS in strawberry fruits.

Table-2: Effect of various nutrient treatments on the physical parameters of strawberry fruit (*Fragaria* x *ananassa* Duch.) cv. Chandler.

Treatments		Weight of berry (gm)	Volume of berry (cc)	Fruit Density (gm/cc)	T.S.S. (°brix)	Titratable acidity (%)	TSS/Acid ratio
Recommended doses of manures and fertilizers- full dose of FYM, P and K as basal + inorganic N in two equal split at establishment and before flowering stage	(T_1)	9.49	8.37	1.14	10.53	0.98	10.79
½ N, full P and K as basal and remaining ½ N before flowering, all through inorganic source	(T_2)	8.60	8.27	1.04	9.07	0.97	9.38
½ N through of FYM + full P and K as basal and remaining and ½ N through inorganic source before flowering	(T_3)	8.80	8.02	1.10	9.73	1.01	9.62
½ N through Vermicompost + full P and K as basal dose remaining ½ N through inorganic source before flowering	(T_4)	9.36	8.39	1.12	10.27	0.99	10.34
½ N through FYM, full P and K at planting + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_5)	9.40	8.32	1.13	10.60	0.88	12.08
½ N through vermicompost + full P and K as basal + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_6)	9.67	8.47	1.14	12.07	0.99	12.19
Azotobacter inoculation, without any manure and fertilizer, @ 2 kg/ha at the time of planting	(T_7)	8.05	7.07	1.14	11.67	1.06	10.97
T_2 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_8)	8.65	8.03	1.08	8.60	0.90	9.54
T_3 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_9)	9.05	8.03	1.13	9.53	0.99	9.63
T_4 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{10})	9.42	8.50	1.11	9.87	0.95	10.39
T_5 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{11})	10.08	8.89	1.13	11.73	0.90	13.07
T_6 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{12})	9.54	8.51	1.12	12.20	0.87	14.08
Control (No manure, fertilizer or Azotobacter inoculation)	(T_{13})	8.88	7.80	1.14	10.60	1.01	10.53
$CD_{0.05}$		NS	NS	0.03	1.03	0.06	1.29

Table-3: Effect of various nutrient treatments on the chemical parameters of strawberry fruit (*Fragaria* x *ananassa* Duch.) cv. Chandler.

Treatments		Total Sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (mg/100g)	Total Phenols (mg/100g)	Anthocyanin pigment
Recommended doses of manures and fertilizers- full dose of FYM, P and K as basal + inorganic N in two equal split at establishment and before flowering stage	(T_1)	6.25	5.04	1.46	60.32	326.13	Red Group 45
½ N, full P and K as basal and remaining ½ N before flowering, all through inorganic source	(T_2)	5.94	4.11	2.04	60.48	347.64	Red Group 42A
½ N through of FYM + full P and K as basal and remaining and ½ N through inorganic source before flowering	(T_3)	5.64	4.65	1.22	48.43	331.63	Red Group 44A
½ N through Vermicompost + full P and K as basal dose remaining ½ N through inorganic source before flowering	(T_4)	5.66	4.75	1.16	43.20	342.14	Red Group 45
½ N through FYM, full P and K at planting + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_5)	5.90	5.02	1.13	59.20	343.14	Red Group 46
½ N through vermicompost + full P and K as basal + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_6)	6.09	5.25	1.10	59.04	340.14	Red Group 46
Azotobacter inoculation, without any manure and fertilizer, @ 2 kg/ha at the time of planting	(T_7)	6.23	5.45	1.05	45.28	321.63	Red Group 43
T_2 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_8)	5.79	4.18	1.82	54.40	338.64	Red Group 44
T_3 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_9)	5.80	4.66	1.38	48.32	325.13	Red Group 46
T_4 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{10})	5.79	4.74	1.29	44.16	342.14	Red Group 44A
T_5 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{11})	5.82	4.76	1.31	53.44	351.14	Red Group 45
T_6 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{12})	5.91	5.00	1.16	59.52	321.13	Red Group 46
Control (No manure, fertilizer or Azotobacter inoculation)	(T_{13})	6.21	5.19	1.28	47.36	344.14	Red Group 43
$CD_{0.05}$		0.21	0.32	0.33	4.40	NS	-

Azotobacter inoculation alone (T_7), unfertilized treatment (T_{13}) and INM through farmyard manure and inorganic N in one split (T_3) have highest titratable acidity in berry. On the other hand, maximum concentration of total sugars in strawberry fruits was observed in the treatments receiving recommended dose of manures and fertilizers (T_1) and INM treatments through vermicompost and inorganic N in two splits irrespective of *Azotobacter* inoculation (T_6 and T_{12}). All the INM treatments (T_5, T_6, T_{11} and T_{12}) and control (T_1) had significantly higher concentration of reducing sugars over inorganic treatments but differences among these were non-significant. These findings are in conformity to Wang and Lin (2002) and Ali *et al.* (2003) who also recorded increase in overall fruit quality of strawberry through addition of organic compost.

Table-4: Effect of various nutrient treatments on the cost benefit ratio of strawberry cultivation (*Fragaria x ananassa* Duch..) cv. Chandler.

Treatments		Treatment expenditure	Gross income (Yield + Runner)	Net Benefit (Rs.)	C/B ratio	Change in net return over Control
Recommended doses of manures and fertilizers- full dose of FYM, P and K as basal + inorganic N in two equal split at establishment and before flowering stage	(T_1)	347355.70	1375476.50	1028120.80	1:3.96	405889.80
½ N, full P and K as basal and remaining ½ N before flowering, all through inorganic source	(T_2)	327259.31	1044715.50	717456.19	1:3.19	95225.19
½ N through of FYM + full P and K as basal and remaining and ½ N through inorganic source before flowering	(T_3)	340834.74	1524259.00	1183424.26	1:4.47	561193.26
½ N through Vermicompost + full P and K as basal dose remaining ½ N through inorganic source before flowering	(T_4)	387518.39	1482978.00	1095459.61	1:3.83	473228.61
½ N through FYM, full P and K at planting + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_5)	341184.74	1582627.00	1241442.26	1:4.64	619211.26
½ N through vermicompost + full P and K as basal + remaining ½ N in two equal doses, each at establishment and before flowering stage- inorganic source	(T_6)	387518.39	1638520.50	1251002.11	1:4.23	628771.11
Azotobacter inoculation, without any manure and fertilizer, @ 2 kg/ha at the time of planting	(T_7)	311090.00	927943.50	616853.50	1:2.98	-5377.50
T_2 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_8)	327459.31	1204706.50	877247.19	1:3.68	255016.19
T_3 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_9)	341034.74	1570590.00	1229555.26	1:4.61	607324.26
T_4 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{10})	387718.39	1528657.00	1140938.61	1:3.94	518707.61
T_5 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{11})	341384.74	1697421.50	1356036.76	1:4.97	733805.76
T_6 + Azotobacter inoculation @ 2 kg/ha at the time of planting.	(T_{12})	387718.39	1762970.00	1375251.61	1:4.55	753020.61
Control (No manure, fertilizer or Azotobacter inoculation)	(T_{13})	310250.00	932481.00	622231.00	1:3.01	0.00

Treatment (T_2) receiving all the fertilization through inorganic source and top dressing of 50% N in one split ha highest concentration of ascorbic acid (60.48%) which is at par with all the INM treatments receiving top dressing of inorganic N in two splits (T_5, T_6 and T_{12}) except treatment T_{11}. All the INM treatments receiving combination of organic and inorganic source of nutrition (T_1, T_3 to T_6 and T_9 to T_{12}) caused marked improvement in the anthocyanin pigmentation of strawberry fruits in comparison to unfertilized and inorganically fertilized treatments (T_2, T_7, T_8 and T_{13}). Yoshida *et al.* (1991 and 2000) observed that total anthocyanin content was lower in nitrogen deficient fruits and concluded that the anthocyanin synthesis in strawberry fruits may be improved with adequate supply of N supply. Integrated nutrient management through combined application of organic manures and inorganic fertilizers have known capability to enhance nitrogen availability to the plant system and improve physico-chemical and microbial activity in the soil. Therefore, improvement in anthocyanin pigmentation in above mentioned INM treatments may be attributed to the enhancement in nitrogen availability to the plant system.

CONCLUSION

The treatment combination comprising of 50% nitrogen through vermicompost along with *Azotobacter* inoculation and remaining 50% through inorganic source in two splits each at establishment of plant and before flowering stages performed best in respect of productivity and quality of strawberry fruits. Enhancement in productivity is combined effect of increased number of flowers and berry, extended duration of harvesting, higher production of 'Extra class' and 'Class-I' berries whereas, improvement in fruit quality is attributed to higher concentration of total soluble solids, total sugars, reducing sugars and ascorbic acid in the fruit pulp. The INM treatment combination was effective in increasing productivity and fruit quality through maintaining enhanced nutrient availability in soil profile under optimum physico-chemical environment.

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