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Integrated nutrient management for strawberry cultivation

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ABSTRACT

A field study was conducted to standardize integrated nutrient supply system for strawberry through various organic, inorganic and biological sources without affecting the yield and fruit quality of strawberry crop at lower cost. Total recommended doses of organic and inorganic fertilizers (50 t/ha farmyard manure and 80, 40, 40 kg/ha N, P_2O_5 and K_2O, respectively) were cumulatively calculated in terms N, P and K and supplied through different combinations and split doses of organic and inorganic sources. Majority of plant growth parameters like number of crown (4.33/plant), number of runners (11.33/plant), length of runners (45.67 cm), number of plantlets (12.53 lakh/ha), and fruit characteristics like number of flowers (29.60/plant), number of berries (22.27/plant) and fruit yield (101.99 q/ha) were recorded maximum in *Azotobacter* inoculated treatment with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage. Number of leaves per plant, duration of flowering and weight of berry were not affected significantly by treatments. Plant growth characters like height (16.65 cm), spread (34.52 cm) and leaf area (108.32 cm^2) were highest in inorganic fertilized plots. However, N substitution by FYM provided highest B:C ratio than vermicompost due to its lower cost of production.

Key words: Strawberry, vermicompost, *Azotobacter*, integrated nutrient management, B:C ratio.

INTRODUCTION

Strawberry (*Fragaria ananassa* Duch.) is a herbaceous perennial plant with shallow adventitious roots system, of which 50-90 per cent is confined to upper 15 cm of the soil profile (Galletta and Bringhurst, 5). The plant is surface feeder and very sensitive to nutrient and soil moisture fluctuations. Although inorganic source of fertilization is very important for the healthy growth and development of the plant, organic and microbial sources of nutrients have advantage of consistent and slow release of nutrients, maintaining ideal C:N ratio, improvement in water holding capacity and microbial biomass of soil profile, without having any adverse residual effects. Therefore, a balanced and integrated supply of various nutrient supplements is of great relevance for the quality and sustainable fruit production.

Vermicompost is gaining popularity and preference over farmyard manure as a richer source of available plant nutrients, growth regulators, enzymes, antifungal and antibacterial compounds (Arancon *et al.*, 3,4). *Azotobacter* is the most intensively investigated free living nitrogen fixing bacteria and, apart from having ability to fix atmospheric nitrogen it is also known to synthesize biologically active growth promoting substances such as IAA, GA, *etc*. Inoculation of *Azotobacter* and *Azospirillum* has great scope to supplement nutritional requirements of the non-leguminous fruit crops (Pathak *et al.*, 9). These exhibited significant improvement in plant growth characters and leaf nutrient content of strawberry when applied in combination with inorganic fertilizers and GA_3 (Singh and Singh, 11). 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 various inorganic, organic and biological sources without affecting the yield and fruit quality of strawberry crop at lower cost.

MATERIALS AND METHODS

The study was conducted by planting uniform size runners of strawberry cv. Chandler on a raised bed measuring 1 m × 1.25 m at a spacing of 25 cm x 50 cm accommodating 10 plants/bed (53,333 plants/ha) in September 2004 at experimental orchard of Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The soil of the experimental field was sandy clay loam; the availability of N, P and K were in medium range and the soil was neutral in reaction. An irrigation channel of 50 cm wide was provided between two beds.

Strawberry is fertilized with 50 tonnes of FYM and 80, 40 and 40 kg/ha of N, P_2O_5 and K_2O respectively from inorganic sources (Anon., 2). The total recommended dose of organic manure and inorganic fertilizers was converted into the form of N, P and K nutrients and

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then the cumulative doses were applied through various combinations of organic manures (FYM: 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 CAN, SSP and MOP for supply of N, P and K, respectively.

The experiment was laid out in a randomized block design with 13 treatments and replicated thrice as suggested by Gomez and Gomez (6). The treatment comprises 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 sources, 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 flowerings (INM with vermicompost and inorganic N in two splits), 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 and T_{13} - no manure, fertilizer or *Azotobacter* inoculation. Phosphorus and potassium were applied basal in all the treatments as per the requirement to balance their respective doses. Other cultural practices like weeding, mulching, hoeing, irrigation, insect pest and disease management were common for all the treatments. Observations of various growth parameters like plant height, plant spread, number of leaves and leaf area were recorded at flower initiation stage, whereas number of crown, number of runners and length of runner per plant were recorded after one year of transplanting. Leaf area was estimated by using LiCor-3100 leaf area meter. Flowering and fruit characteristics, *viz.* number of flowers per plant, per cent berry set, number of berries per plant, average weight of berry, duration of flowering and harvesting were recorded and compiled treatment-wise. Fully matured berries were harvested and fruit parameters were recorded plantwise as well as treatmentwise and converted into yield on hectare basis. Economic analysis of different nutrient treatments was carried out from total cost and income to identify the most remunerative system. The data recorded from the present investigations were analysed statistically and mean differences were compared to study treatment effects.

RESULTS AND DISCUSSION

Various treatment combinations produced significantly different plant growth, fruit yield and net return over control. Maximum growth in terms of plant height (16.65 cm), plant spread (34.52 cm) and leaf area (108.32 cm^2) were observed in 100% inorganic fertilized treatments. Whereas, highest values of post-harvest plant growth characters like number of crown (4.33/plant), number of runners (11.33/plant), length of runners (45.67 cm) and number of plantlets (12.53 lakhs/ha) were observed with *Azotobacter* inoculated treatment in which 50% of N was substituted by vermicompost and remaining 50% N was added by top dressing in two equal split doses each at establishment and before flowering stages (Table 1). A comparison of improved treatment combination over recommended practice showed that only 100 percent inorganic treatment with (T_8) and without inoculation (T_2) produced significantly higher plant height, plant spread and leaf area over control. Whereas, the post-harvest plant growth characters like number of crowns per plant, number of runners per plant, length of runners and number of plantlets per hectare was significantly higher in *Azotobacter* inoculated treatment in which 50% of N was substituted by vermicompost and remaining 50% N was added by top dressing in two equal split doses each at establishment and before flowering stages (T_{12}) over inorganic fertilized treatments (T_2 & T_8) and over control in respect of number of runner per plant and number of plantlets per hectare. Substitution of 50% N by FYM proved less effective than vermicompost due to slow release of nutrients. Similarly, split application of remaining half N in two instalments at establishment and before flowering proved better than single application before flowering with both FYM and vermicompost because of better availability over entire growth period. The finding revealed that inorganic fertilized treatments recorded maximum growth in respect of pre-harvest plant growth characters because of quick release and availability of nutrients whereas, post-harvest plant growth characters were recorded highest in *Azotobacter* inoculated INM with vermicompost and inorganic nitrogen in two split doses. The above results are in conformity with the findings of Swarup *et al.* (12) who reported that the integrated nutrient management with combination of organic and inorganic sources requires time to influence crop growth through improvement in soil physical, chemical and biological properties. The difference in number of leaves remained non-significant among all

Table 1. Effect of various combinations of nutrients on the vegetative growth and runner production of strawberry cv. Chandler.

Treatment	Plant height (cm)	Plant spread (cm)	No. of leaves/ plant	Leaf area (cm^2)	No. of crowns/ plant	No. of runners/ plant	Length of runners (cm)	No. of plantlets (lakhs/ha)
T_1	13.40	27.25	19.28	81.34	3.33	8.00	40.67	9.07
T_2	16.55	34.52	19.38	107.74	2.67	6.33	32.33	7.20
T_3	14.24	27.37	16.32	72.24	3.67	10.67	41.33	11.47
T_4	14.31	27.46	21.80	89.51	3.33	10.00	43.67	10.67
T_5	15.33	28.85	20.55	83.94	4.00	9.67	43.33	10.93
T_6	15.51	29.41	21.32	101.77	3.67	10.67	44.33	11.47
T_7	11.43	20.65	15.95	63.50	2.33	6.33	29.00	6.93
T_8	16.65	33.37	19.73	108.32	3.00	8.00	35.33	8.80
T_9	14.48	28.19	18.43	100.13	4.33	10.33	42.67	11.73
T_{10}	14.93	27.99	20.40	95.99	4.00	9.67	43.00	10.93
T_{11}	15.64	29.46	19.46	87.94	4.33	10.67	44.00	12.00
T_{12}	15.66	30.27	24.13	104.52	4.33	11.33	45.67	12.53
T_{13}	11.10	19.38	11.27	62.19	2.67	6.67	32.67	7.47
$CD_{0.05}$	2.99	6.58	NS	24.25	1.13	2.94	8.12	2.61

the treatments including control. These results are in conformity with the findings of Arancon *et al.* (3) who reported that integrated nutrient management using vermicompost, *Azotobacter* and inorganic fertilizers didnot influence number of leaves per plant in strawberry cv. Chandler. Rana and Chandel (10) observed that nitrogen integration using combination of inorganic N and *Azotobacter* inoculation produced maximum plant height, number of leaves and leaf area in strawberry cv. Chandler. Kukkonen and Vesalo (8) recorded better performance, *i.e.* 33% more number of strawberry runners with *Azotobacter* inoculation.

In general, 50% N replacement with vermicompost and remaining 50% in two equal split doses gave best performance of above mentioned growth parameters under both groups, *i.e.* inoculated and un-inoculated. Reported benefit on account of integration of vermicompost, *Azotobacter* and inorganic fertilizers were due to improved soil aeration, regulated temperature, moisture, and macro and micronutrients status of the soil (Arancon *et al.,* 3). These factors provide suitable environment for nutrients uptake and translocation by the plants. The plants exhibited the excellent growth, which was depicted through various growth parameters. Addition of vermicompost also added plant growth regulators by substantial increase in microorganisms during vermicomposting (Arancon *et al.,* 3).

Highest values of fruiting characters like number of flowers (29.60/plant), percent berry set (76.23), number of berries (22.27/plant), weight of berry (10.08 g), duration of flowering (142.33 days), duration of harvesting (71.67 days) and fruit yield (101.99 q/ha) were also recorded in the INM treatments having 50% N replacement by vermicompost and remaining inorganic N in two splits (T_{12} & T_6, Table 2). Weight of berry proved an exception which was reported highest in *Azotobacter* inoculated INM with farmyard manure and inorganic N in two splits. However, no significant improvement was reported in respect of weight of berry and duration of flowering. It is evident from the observations that the integration of organic and inorganic nutrient sources caused significant difference in fruit characters like number of flowers per plant, percent berry set and number of berries over non-INM treatments (T_2, T_7, T_8 and T_{13}). Split application of 50% N through inorganic sources at two times (at establishment and before flowering) was effective than single application before flowering in INM treatments. However, the differences between the INM treatments are not statistically significant. The effect of *Azotobacter* inoculation did not show any significant influence over there respective un-inoculated treatments. Same trend was also observed for duration of the harvesting. The best performance of majority of fruiting characteristics was recorded under *Azotobacter* inoculated treatment with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage (T_{12}), while un-inoculated treatment with 50% N substitution by vermicompost and remaining 50% through inorganic fertilizer in two equal splits at establishment and

Table 2. Effect of various combinations of nutrients on the fruiting of strawberry cv. Chandler.

Treatment	No. of flowers/ plant	Percent berry set	No. of berries per plant	Weight of berry (g)	Duration of flowering (days)	Duration of harvesting (days)	Yield (q/ha)	B:C ratio
T_1	28.60	70.34	20.13	9.49	129.00	65.67	93.70	3.96
T_2	22.83	65.25	14.90	8.60	132.00	55.33	64.94	3.19
T_3	25.47	73.50	18.67	8.80	124.33	63.67	75.45	4.47
T_4	26.63	73.54	19.63	9.36	134.00	61.67	83.20	3.83
T_5	28.43	75.25	21.40	9.40	134.33	66.00	97.92	4.64
T_6	28.87	76.23	22.07	9.67	133.33	71.67	98.30	4.23
T_7	21.47	62.57	13.43	8.05	125.00	61.67	46.99	2.98
T_8	24.87	61.66	15.33	8.65	136.00	59.67	64.94	3.68
T_9	26.40	71.90	18.97	9.05	134.00	62.67	79.52	4.61
T_{10}	25.13	75.17	18.90	9.42	129.33	61.00	87.13	3.94
T_{11}	27.93	75.84	21.23	10.08	138.00	67.67	99.48	4.97
T_{12}	29.60	75.23	22.27	9.54	142.33	67.33	101.99	4.55
T_{13}	15.20	57.18	8.73	8.88	124.33	49.67	37.09	3.01
$CD_{0.05}$	4.14	3.73	3.41	NS	NS	7.75	11.91	

before flowering stage (T_6) recorded highest percent berry set and extended the duration of harvesting. All the benefits on growth and fruit characteristics were reflected in fruit yield. These findings are in line with the findings of Kopanski and Kawecki (7), Wang and Lin (14), Turemis (13), and Ali *et al.* (1). Kopanski and Kawecki (7) recorded the highest average yield when 40 t/ha FYM were applied with 30 kg/ha N in two equal split doses in their trial based on various combinations of nitrogen and FYM. They also observed that higher rate of N (90 kg/ha) through inorganic sources reduce the yield in strawberry cvs. Sena Sengana and Dukat. However, splitting in nitrogen dose was found beneficial for the reproductive growth of the plant. Wang and Lin (14) recorded increase in fruit yield by more than 70%, fruit size by 15% when half of the fertilizer was added in a mixture of 50% soil and 50% compost. Similarly, Turemis (13) reported that the application of compost accelerated bloom date of strawberry plants in comparison to control. Ali *et al.* (1) recorded higher number of flowers, more fruits set, high fruit retention, more fruit weight and high fruit yield under combined application of nitrogen, phosphorus and farmyard manure (N-150 kg/ha, P-100 kg/ha and FYM-20 t/ha). The increase in fruiting characteristics under present studies may be due to the capability of vermicompost in producing growth hormones, enzymes, antifungal and antibacterial compounds, which in turn enhanced these parameters over other treatments. Beneficial effects of *Azotobacter* were due to the fixation of atmospheric nitrogen and improvement in these parameters. Wange (15) reported that application of *Azotobacter* with 150 kg inorganic N per hectare increased yield by 54% compared with applying 150 kg N per hectare alone.

Economic analysis of various treatments revealed that *Azotobacter* inoculated treatment with 50% N substitution by farmyard manure and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage (T_{11}) gave the highest B:C ratio (4.97) which is 125% over control. The treatment with 50% N substitution by vermicompost manure and remaining 50% through inorganic fertilizer in two equal splits at establishment and before flowering stage (T_{12}) recorded lower B:C (115% over control) ratio though having higher fruit yield is due to higher cost of vermicompost in treatment (T_{12}). However, the net monetary return was reported highest with treatment T_{12}. This increase in monetary return is due to the higher yield of berry as well as runners production. It was also noticed that splitting of doses and change in proportion of organic and inorganic sources of nutrients significantly enhanced the net monetary return over recommended doses of manures and fertilizers (T_1 control). Application of 50% N in two splits in INM treatments resulted in higher B:C ratio than application of inorganic N in single dose.

A very high dose of farmyard manure @ 50 t/ ha is recommended with NPK (80:40:40 kg/ha) to attain sustainable production of strawberry. Treatment combination with varying proportion of organic and inorganic sources with and without *Azotobacter* inoculation showed that 50 percent N substitution through vermicompost (16.5 t/ha) with *Azotobacter* inoculation produced maximum plant growth and fruit yield and provided highest net returns. Similar substitution with farmyard manure (33 t/ha) performed statistically at par. Rather farmyard manure substitution provided higher benefit-cost ratio due to its lower cost. Secondly, application of remaining 50% N in two splits in INM treatments at the establishment and before flowering stage had beneficial effect on all plant growth and fruiting characters and provided higher net returns and benefit-cost ratio. These studies, thus conclusively established that higher dose of FYM can be lowered for sustainable yield and higher return through scientifically planned integrated nutrient management supply.

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REFERENCES

1. Ali, Y., Masood, I., Shah, S.Z.A. and Ahmad, M.J. 2003. Effect of different combinations of nitrogen, phosphorus and farmyard manure on yield and quality of strawberry. *Sarhad J. Agric.* **19**: 185-88.

2. Anon. 2003. *Package of Practices for Fruit Crops*. Directorate of Extension Education, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. pp. 98-99.

3. Arancon, N.Q., Edward, C.A., Bierman, P., Welch, C. and Metzger, J.D. 2004. Influences of vermicompost on field strawberries: Effect on growth and yields. *Bioresource Tech.* **93**:145-53.

4. Arancon, N.Q., Galvis, P., Edward, C. and Yardim, E. 2002. The tropic diversity of nematode communities in soil treated with vermicompost. *Pedobiologia 2003,* **47**: 736-40.

5. Galletta, G.J. and Bringhurst, R.S. 1990. Strawberry management. **In**: *Small Fruit Crop Managament.* Gene J. Galletta and David G. Himelrick, (Eds.). Prentice Hall, Englewood Cliffs, New Jersey. pp. 96-97.

6. Gomez, K.A. and Gomez, A.A. 1983. *Statistical Procedures for Agricultural Research* (2nd edn.). John Willey and Sons, New York, 680 p.

7. Kopanski, K. and Kawechi, Z. 1994. Effect of fertilizing with nitrogen and FYM on growth and cropping in two strawberry cultivars in conditions of Zuawy Wislane. *Roczniki Gleboznawcze,* **45**: 67-75.

8. Kukkonen, S. and Vesalo, S. 2000. Indication of soil degradation in strawberry fields; Disappearance of earthworms. **In**: *DIAS Report, Plant Production* **38**: 99-108.

9. Pathak, R.K., Ram, R.A. and Mishra, M. 2003. Nutrient management in fruit crops of Uttar Pradesh and Uttaranchal: An overview. **In**: *Nutrient Status, Needs and Recommendations for Major Fruit Crops of Uttar Pradesh and Uttaranchal.* Proceeding of Workshop. 10-11 Dec 2002, CISH, Lucknow, R.K. Pathak and K.N. Tiwari, (Eds.). Central Institute of Subtropical Horticulture, Lucknow, India. pp. 1-2.

10. Rana, R.K. and Chandel, J.S. 2003. Effect of biofertilizers and nitrogen on growth, yield and fruit quality of strawberry. *Prog. Hort.* **35**: 25-30.

11. Singh, A. and Singh, J.N. 2009. Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. *Indian J. Hort.* **66**: 220-24.

12. Swarup, A., Reddy, D.D. and Prasad, R.N. 1998. Long-term soil fertility management through integrated plant nutrient supply. *All India Co-ordinated Research Project on Long-Term Fertilizer Experiments.* Indian Institute of Soil Science, Bhopal. 335 p.

13. Turemis, N. 2002. The effect of different organic deposits on yield and quality of strawberry cultivar Dorit (216). **In**: *Proceeding of 4th International Symposium. Acta Hort.* **567**: 507-8.

14. Wang, S.Y. and Lin, S.S. 2002. Compost as soil supplement enhanced plant and fruit quality of strawberry. *J. Plant Nutr.* **25**. 2243-58.

15. Wange, S.S. 1996. Response of strawberry to combined application of diazotrophs and fertilizer nitrogen. *J. Soils Crops,* **6**: 100-101.

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