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Effect of integrated nutrient management on plant growth, yield and quality parameter of strawberry (*Fragaria x ananassa* Duch.) Var. Winter Dawn

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Abstract
The experiment was carried out at Agriculture Research Farm of Rama University, Mandhana, Kanpur, U.P, India, during October 2022-2023 to investigate the effect of integrated nutrient management on plant growth, yield and quality Parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn" eight treatments *viz.,* T_1 (Control), T_2 (100% RDF N: P: K @ 6:10:6 g/plant), T_3 (100% RDF + *Azotobacter* @ 2g/plant), T_4 (100% RDF + *Azospirillum* @ 2g/plant), T_5 (50% RDF + *Azotobacter* @ 2g/plant + topdressing of 50% each of P and K), T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K), T_7 (50% RDF + *Azotobacter* @ 2g/plant + PSB @2g/plant + topdressing of 50% K) and T_8 (50% RDF + *Azospirillum* @ 2g/plant + PSB @2g/plant + topdressing of 50% K) along with their combinations, replicated thrice in a Randomized Block Design. In strawberry use the application of fertilizer with bio-fertilizer like *Azotobacter* and *Azospirillum* hasten early flowering along with the expanded duration of blossoming, harvesting by increasing the growth, yield and quality of strawberry. The integrated nutrient management maximized plant height (cm), number of leaves per plant, plant area (cm^2), number of runners per plant, number of flowers per plant, number of berries per plant, fruit weight (g), fruit length (mm), fruit diameter (mm), fruit yield/plot (kg), total soluble solids, ascorbic acid (mg/100g), total sugars (%) and minimize the days taken to first flower and titratable acidity (%).

Keywords: Azotobacter, Azospirillum, *Fragaria x ananassa*

Introduction
Strawberry (Fragaria × ananassa Duch.) is a high value and low volume crop belonging to the family Rosaceae. The cultivated varieties are octaploid (2n=8x=56) in nature and has been derived from North American species, Fragaria chiloensis and Fragaria verginiana in France in the 17th century. Strawberry is one of the most important temperate fruits, it can also grow in sub-tropical and tropical regions (Sharma and Badiyala, 1980) [12]. Strawberry successfully grown up to 3000 meters, above mean sea level in humid and dry regions. Being a quick growing crop, it is also suitable for kitchen garden. In India Haryana is the leading state in India both in area and production (93.28), (4.26) followed by Maharastra production (3.28), Punjab, Uttar Pradesh is least growing state of India, Jammu and Kashmir, Uttarakhand and lower hills of Himachal Pradesh with a total area of 0.21 thousand ha and production of 1.61 thousand MT (Anon. 2021) [1]. The fruits of strawberry are attractive with distinct aroma and pleasant flavour, proteins and minerals like P, K, Ca and Fe (Joolka, 1983) [5]. Nutritionally, strawberry is a low-calorie carbohydrate fruit but a rich in source of vitamin A (60 IU/100g of edible portion), vitamin C (30-120mg/100g of edible portion), fiber (1.1%) and also has high pectin content (0.55%) available in the form of calcium pectate. Water is a major constituent (90%) of strawberry fruit. Elegiac acid is a naturally occurring plant phenol. It has been found to inhibit the cancer disease and asthma by the regular consumption of its fruits. It is also rich source of Thiamine (0.03 mg/100g), Riboflavin (0.01 mg/100g) and Nicotinic acid (0.2 mg/100g). The beneficial microorganisms present in the biofertilizers not only able to improve the plant growth but also maintained the environmental health and productivity of the soil. Among the various factors which contribute towards the growth, yield and quality of strawberry, nutrition is the most important and it has direct effect on bearing and production (Umar *et al.,* 2009) [15]. The basic principle behind this concept is to supply both the chemical fertilizers with bio-fertilizers for a sustainable crop production in most efficient manner. Adoption of integrated nutrient management practices in strawberry is more essential to realize higher yield, quality and returns.

Materials and Methods

The present investigation on the effect of integrated nutrient management on plant growth, yield and quality Parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn was carried out during the October 2022-23 at Agriculture Research Farm of Rama University, Mandhana, Kanpur, which is located in the alluvial belt of Gangetic plains of central Uttar Pradesh. For this an experiment was planned using eight treatments *viz.*, T_1 (Control), T_2 (100% RDF N: P: K @ 6:10:6 g/plant), T_3 (100% RDF + *Azotobacter* @ 2g/plant), T_4 (100% RDF + *Azospirillum* @ 2g/plant), T_5 (50% RDF + *Azotobacter* @ 2g/plant + topdressing of 50% each of P and K), T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K), T_7 (50% RDF + *Azotobacter* @ 2g/plant + PSB @2g/plant + topdressing of 50% K) and T_8 (50% RDF + *Azospirillum* @ 2g/plant + PSB @2g/plant + topdressing of 50% K) along with their combinations, replicated thrice in a Randomized Block Design. The healthy, uniform and disease-free runners of "winter dawn" cultivar was procured from Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) and transplanted at 30×30cm spacing on October 6th during 2022. Other cultural practices including irrigation, insect-pests and disease management were common in all treatments. The observations were recorded from each treatment of all three replication. Five plants of strawberry were selected randomly and tagged under each treatment for recording different vegetative attributes *viz.*, plant height (cm), number of leaves per plant, plant area (cm^2), days taken to first flower, number of runners per plant, number of flowers per plant, number of berries per plant, fruit weight (g), fruit length (mm), fruit diameter (mm), fruit yield/plot (kg), total soluble solids, ascorbic acid (mg/100g), titratable acidity (%) and total sugars (%).

Results and Discussion

The data on the effect of integrated nutrient management on plant growth, yield and quality parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn characters *viz.*, Vegetative Growth, Yield and Quality parameter of strawberry.

Vegetative growth parameter

The data on effect of integrated nutrient management on vegetative growth parameter *viz.*, plant height (cm), number of leaves per plant, leaf area (cm^2), days taken to first flower, number of runners per plant, number of flowers per plant are presented in Table-1.

The plant height and number of leaves was significant differences among the treatments at 30, 60 and 90 DAT. The maximum plant height (5.80, 9.56 and 15.76cm) and number of leaves (4.32, 12.67 and 18.13) at 30, 60 and 90 DAT per plant were obtained in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K) treated plants. The minimum plant height (3.89, 6.55 and 11.18cm) and number of leaves (2.43, 10.15 and 14.68) were recorded with T_1 (control). These findings are in agreement with the reports of Marathe and Bharambe (2005) [8] in sweet orange, Nowsheen *et al.* (2006) [9] and Tripathi *et al.* (2010) [14] in strawberry.

The effect of integrated nutrient management on maximum leaf area (121.09 cm^2), number of flower (27.65), number of runners per plant (4.80) and minimum days taken to first flower (27.12) were recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) leaf area (102.07 cm^2), number of flowers (18.62), number of runners per plant (1.32) and maximum days taken to flowering (40.12). These findings are in complete agreement with Nowsheen *et al.*, (2006) [9] and Umar *et al.*, (2009) [15] in strawberry working with strawberry noted similar results. The increase in vegetative growth and other parameters might be due to the production of more chlorophyll content with inoculation of nitrogen fixers. The other reason for increased vegetative growth may be the production of plant growth regulators by microorganism in rhizosphere, which are absorbed by the roots. Therefore, increased vegetative growth may be attributed to the increased biological nitrogen fixation. Better development of root system and the possibly synthesis of plant growth hormones like IAA, GA and Cytokinins and direct influence of bio-fertilizers might have caused increase in vegetative growth parameters.

Table 1: Effect of INM (Integrated nutrient management) on vegetative growth parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn

Treatments	Plant Height (cm)			Number of leaves			Leaf area (cm^2)	Days taken to first flower	Number of runners /plants	Number of flower / plants
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP				
T_1	3.89	6.55	11.18	2.43	10.15	14.68	102.07	40.12	1.32	18.62
T_2	4.09	8.45	12.69	3.69	11.78	15.09	105.16	36.67	2.70	24.32
T_3	4.98	8.63	13.56	3.87	11.97	15.45	110.19	35.00	3.08	25.89
T_4	5.45	9.03	14.87	4.14	12.23	16.65	112.04	35.19	3.17	25.92
T_5	5.73	9.23	14.89	4.25	12.09	17.66	119.13	28.23	4.65	26.34
T_6	5.80	9.56	15.76	4.32	12.67	18.13	121.09	27.12	4.80	27.65
T_7	4.72	8.78	13.74	3.95	12.00	18.03	112.16	34.65	3.25	23.55
T_8	5.21	9.42	14.98	4.12	12.32	17.89	113.05	35.88	3.72	34.98
S.Em(±)	0.054	0.125	0.135	0.080	0.163	0.263	1.421	0.524	0.051	0.409
C.D. (P=0.05)	0.166	0.382	0.413	0.246	0.499	0.805	4.353	1.605	0.155	1.253

Yield Parameter

The data on effect of integrated nutrient management on yield parameter *viz.*, number of berries per plant, fruit weight (g), fruit length (mm), fruit diameter (mm) and fruit yield per plot (kg) are presented in Table-2.

The effect of integrated nutrient management on maximum number of berries per plant (22.09) were recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) number of berries per plant (12.78). These findings are in line with the Gajbhiye *et al.*, (2003) [4] and Shukla *et al.*, (2009) [13] in tomato.

The maximum fruit weight (21.65g) and fruit yield per plot (2.95kg) were recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) fruit weight (16.54g) and fruit yield per plot (1.96 kg). These findings are in line with the Wange *et al.*, (1998) [16] in strawberry, Kadlag *et al.*, (2007) [6] in tomato and Tripathi *et al.*, (2010) [14] in strawberry.

The increase in fruit size (length 6.90mm and diameter 4.67mm) during the present investigation might be due to the increased photosynthetic ability of plants fertilized with T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) fruit length 3.54 mm diameter 2.23 mm. Fruit size highly correlated with dry matter content and balance level of hormone and nitrogen fixers are known for accumulation of dry matter and their translocation (Kachot *et al.*, 2001) [7] as well as synthesis of different growth regulators.

Table 2: Effect of INM (Integrated nutrient management) on yield parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn.

Treatments	Number of berries per plant	Fruit weight (g)	Fruit yield/plot (kg)	Fruit length (mm)	Fruit diameter (mm)
T_1	12.78	16.54	1.96	3.54	2.23
T_2	18.54	18.87	2.11	4.22	2.89
T_3	19.07	19.04	2.15	5.67	3.65
T_4	19.78	19.45	2.88	5.42	3.34
T_5	21.34	20.84	2.91	6.43	4.32
T_6	22.09	21.65	2.95	6.90	4.67
T_7	20.13	20.34	2.21	5.80	3.92
T_8	19.98	21.00	2.25	6.04	3.90
S.Em(±)	0.218	0.268	0.052	0.110	0.055
C.D. (P=0.05)	0.667	0.819	0.159	0.337	0.169

Quality Parameter

The data on effect of integrated nutrient management on quality parameter *viz.*, total soluble solids (TSS ^oBrix), ascorbic acid (mg/100g), titratable acidity (%) and total sugars (%) are presented in Table-3.

The effect of integrated nutrient management on maximum total soluble solids (6.30^{o}Brix) and total sugars (8.92%) were recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) number of berries per plant (12.78). Total soluble solids (5.11^{o}Brix) and total sugars (5.87%). Increase in TSS and total sugar contents with application of treatment may be attributed to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits. These findings are in agreement with the result of Singh *et al.*, (2009) [11] in ber, Baksh *et al.*, (2008) [3] in guava, Attia *et al.*, (2009) [2] in banana.

The maximum ascorbic acid (58.07 mg/100g) were recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These traits were minimum under T_1 (control) ascorbic acid (44.09mg/100g). The respective increase in ascorbic acid content might be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen, increase in availability of phosphorous and secretion of growth promoting substances which accelerates the physiological process like carbohydrates synthesis etc. The results also got the support with the findings of Tripathi *et al.*, (2010) [14], Yadav *et al.*, (2010) [17] and Umar *et al.* (2009) [15] in strawberry.

The maximum titratable acidity (0.68%) was recorded in the berries which were produced from the unfertilized plants (control), whereas the minimum acidity (0.55%) was recorded in T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). These findings are in line with the Singh *et al.*, (2009) [11] in ber, Baksh *et al.*, (2008) [3] in guava and Rathi and Bist (2004) [10] in pear.

Table 3: Effect of INM (Integrated nutrient management) on quality parameter of strawberry (*Fragaria x ananassa* Duch.) var. winter dawn

Treatments	T.S.S (^{o}Brix)	Total Sugars (%)	Ascorbic acid (mg/100g)	Titratable acidity (%)
T_1	5.11	5.87	44.09	0.68
T_2	5.34	6.64	48.13	0.66
T_3	5.87	6.89	52.18	0.63
T_4	6.04	7.09	52.54	0.63
T_5	6.17	8.87	57.92	0.58
T_6	6.30	8.92	58.07	0.55
T_7	5.90	7.76	52.77	0.60
T_8	5.92	7.45	54.09	0.62
S.Em(±)	0.088	0.143	1.001	0.007
C.D. (P=0.05)	0.268	0.439	3.065	0.022

Conclusion

Based on the results obtained from the present investigation, it is conducted that the highest vegetative growth, yield and quality parameters *viz.*, plant height at 30, 60 and 90 DAT (5.80, 9.56 and 15.76cm), number of leaves per plant at 30, 60 and 90 DAT (4.32, 12.67 and 18.13), leaf area (121.09 cm^2), minimum days taken to flowering (27.12), number of runners per plant found (4.8), number of flower (27.65), number of berries per plants (22.09), fruit weight (21.65g), fruit length (6.90mm), Fruit diameter (4.67mm), fruit yield/plot (2.95kg), total soluble solids (6.30^{o}Brix), ascorbic acid (58.07mg/100g), maximum acidity percentage (0.68%) recorded in T_1, maximum total sugar (8.92%) were observed with the treatment T_6 (50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K). From this study it can be recommend that the application of INM at 50% RDF + *Azospirillum* @ 2g/plant + topdressing of 50% each of P and K a can be applied to obtain maximum vegetative growth, yield and quality of Strawberry.

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