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Influence of bio-fertilizers and bio-regulators on growth, yield and quality of strawberry (*Fragaria* × *ananassa*)

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ABSTRACT

The present investigation was carried out during 2010-2012 to find out the effect of integration of bio-fertilizers with organic manures and inorganic fertilizers on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Festival. The growth, yield and quality of strawberry fruits were significantly influenced by integration of bio-fertilizers, organic manure and inorganic fertilizers. The maximum growth in terms of plant height, spread and number of crowns/plant were observed in the treatment consisting of 75 % RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA3+ 50 ppm BA. This treatment also exhibit superiority in yield attributing characters like number of runners/plant, berry set percentage, berry weight, number of berries/plant and yield/ha. The quality parameters of the fruit like TSS, titrable acidity, ascorbic acid, total sugars and reducing sugars were also influenced by combined use of organic, inorganic and biological sources of nutrients. Significant to highly significant positive correlation was observed among different growth and yield attributing characters with yield.

Key words: Bio-fertilizers, Bio-regulators, Growth, Quality, Strawberry, Yield

Strawberry (*Fragaria* × *ananassa* Duch.), an aggregate fruit, has attained the status of being one of the most important soft fruit of the world after grapes (Umar *et al*. 2008). Botanically an octaploid (2n=56), dicotyledonous, low growing herb grown in most arable regions of the world and enjoyed by millions of people in all kinds of climates (Kumar *et al*. 2012). Among the fruits, it is one of the most popular, delicate in flavour, rich in vitamins and minerals and gives quickest return in the shortest possible time (Singh and Singh 2009). The fruits are also good sources of natural antioxidants including carotenoides, vitamins, phenols, flavonoides, dietary glutathionine and endogenous metabolites and exhibit high level of antioxidant capacity against free radical species (Wang and Jiao 2000, Singh *et al*. 2008).

Organic and microbial sources of nutrients have advantage of consistent and slow release of nutrients, maintaining ideal C: N ratio, improvement of water holding capacity and microbial biomass of soil profile without having any residual effects (Yadav *et al.* 2010). Application of organic manures not only improve soil physical properties and pH, but also add essential nutrients to the soil, thus increases the nutrient availability and its ultimate absorption by plant (Hazarika *et al.* 2014). Uses of organic manures are environmentally safe and viable alternatives of chemical fertilizers and it increases microbial biomass in the soil (Selvamani *et al.* 2011). Bio-fertilizers can promote plant growth and productivity has internationally been accepted as an alternate source of chemical fertilizers (Mia *et al.* 2010). They have been found to promote synthesis of growth promoting substances like auxins, gibberellins, cytokinins and antibiotic metabolites which, in turn, improved resistance against biotic and abiotic stress (Awasthi *et al*. 1998). Inoculation of these N-fixing microorganisms in the soil not only increases the yield but also save 20-40% nitrogen inputs. In addition to organic manures and bio-fertilizers, the bio-regulators also play an important role in growth and yield of fruit crops. Some of the plant bio-regualtors are synthesized endogenously, but occasionally they are needed to be supplemented exogenously for additional stimulus for short duration crops like strawberry, which require quick response for increased growth, fruit set and yield. So, Integrated Nutrient Management (INM) is an integrated approach by involving all available resources, viz organic, inorganic, microbial inoculants and bio-regulators is the only alternatives for sustainable production and economic yield of strawberry. INM paves the way to overcome the problems associated with chemical fertilizers to sustain crop production as well as maintaining of soil health (Yadav *et al.* 2011). It maintains

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the soil fertility to an optimum level, improves farmer's profitability through judicious use of chemical fertilizers, organic manures, vermicompost and bio-fertilizers. In addition, ecologically sound and economically viable long term sustainability of productivity could be achieved only through interaction of inorganic and organic sources of nutrients (Nambair and Abrol 1989, Hedge *et al*. 1992 and Singh and Yadav 1992). Keeping in view all the above background information, the present investigation was undertaken to find out the effect of combined application of bio-fertilizers and bio-regulatos for growth, yield and quality of strwberry cv. Festival in Mizoram condition, India.

MATERIALS AND METHODS

The present investigation was conducted at research orchard, Department. of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl, India during 2010-12. The soil of the experimental plot was sandy loam; the available N, P and K were 270.45 kg/ha, 28.76 kg/ha and 119.45 kg/ha with 0.57% organic carbon and the soil was acidic in reaction with soil pH 4.97. The experiment was laid out in a Randomized Block Design (RBD) with 12 treatments and 3 replications. Required quantity of vermicompost @ 5 tonnes/ha was applied before transplanting of strawberry runners in the respective plots as per scheduled treatments. *Azospirillum* and PSB culture were mixed in ten per cent molasses slurry and the roots of the runners were thoroughly dipped in the slurry before planting. After two months of planting, the soil was also inoculated with *Azospirillum* and PSB @ 2 kg/ha. The recommended dose of P_2O_5 and K_2O @ 80 kg and 100 kg/ha in the form of single super phosphate and muriate of potash were applied at the time of field preparation. The recommended N @120 kg/ha, in the form of urea was applied in two split doses, half after one month of planting and the second half after flowering.

The various treatments comprising of organic manures, chemical fertilizers, bio-fertilizers and bio-regulators were as follows: T_1 = Recommended dose of Fertilizer (RDF) + vermicompost, T_2 = 75% RDF + vermicompost + *Azospirillum,* T_3 = 75% RDF + vermicompost + PSB, T_4 = 50% RDF + vermicompost + PSB + *Azospirillum*, T_5 = 75% RDF + vermicompost + PSB + *Azospirillum,* T_6 = 50 % RDF + vermicompost + PSB + *Azospirillum* + 100 ppm GA_3, T_7 = 75 % RDF + vermicompost + PSB + *Azospirillum*+ 100 ppm GA_3, T_8= 50% RDF + vermicompost + *Azospirillum* + PSB + 100 ppm BA, T_9= 75 % RDF + vermicompost + *Azospirillum* + PSB + 100 ppm BA, T_{10} = 50% RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA_3+ 50 ppm BA, T_{11}= 75 % RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA_3+ 50 ppm BA, T_{12} = Control.

Standard methods were followed to take the observations on various growth and yield characters. Plant growth characters of five plants from the middle of each plot were selected randomly for observation and tagged for subsequent record. The leaf area was recorded with Li-Cor 3100 leaf area meter and expressed in square centimeter (cm^2). Per cent berry set was worked out with a formula given by Westwood (1979). Twenty berries from each treatment were randomly selected to record the data on physico-chemical characters. The total soluble solids were determined with Zeiss Hand Brix Refractometer (0-32 °B). The titratable acidity, sugars and ascorbic acid were determined by method as suggested in AOAC (1989). Data were subjected to ANOVA (Gomez and Gomez 1984), where appropriate means were separated with least significant difference analysis. To establish the relationship between various parameters, the data were subjected to correlation studies.

RESULTS AND DISCUSSION

The maximum growth in terms of plant height (25.85 cm), plant spread (27.42 cm), crowns/plant (6.30) were observed in T_{11} (Table 1). The increased vegetative growth may be attributed due to the increased biological nitrogen fixation, better organic nitrogen utilization, better

Table 1 Effect of bio-fertilizers and bio-regulators on growth growth characteristics of strawberry cv. Festival

Treatment	Plant height (cm)	Plant spread (cm)	Leaves/ plant (cm)	Leaf area/ plant(cm^2)	Crowns/ plant	Runners/ plant	Duration of flowering (Days)	Duration of fruiting (Days)
T_1	21.73	22.52	22.27	105.63	4.40	5.78	62.84	62.38
T_2	22.30	22.82	21.22	119.15	4.87	5.88	66.35	65.02
T_3	22.63	22.69	22.37	119.45	4.92	5.97	55.07	53.75
T_4	23.80	25.08	24.00	123.08	5.20	6.23	58.85	58.52
T_5	23.90	25.38	24.20	116.43	5.63	6.60	57.97	57.72
T_6	23.63	25.39	24.32	112.22	5.68	6.87	72.97	77.43
T_7	24.30	24.06	24.65	124.27	5.27	6.97	78.77	72.30
T_8	24.48	24.36	25.42	125.59	5.53	7.02	75.37	74.33
T_9	24.78	24.28	25.38	124.61	5.72	7.22	68.77	64.05
T_{10}	25.23	25.92	26.85	128.78	5.67	7.38	65.38	67.87
T_{11}	25.85	27.42	25.56	126.13	6.30	7.45	68.83	67.43
T_{12}	19.32	22.55	22.07	107.26	4.83	4.73	60.52	56.95
CD (P=0.05)	1.64	1.09	0.91	3.43	0.33	1.19	4.32	4.90

development of root system and the possible synthesis of plant growth regulators like IAA, GA and cytokinins (Martinez *et al.* 1997). Awasthi *et al*. (1998) reported that increase in plant growth may be related to general role of bio-fertilizers in stimulating nutrients uptake especially nitrogen which has role in the assimilation of numerous amino acids that are subsequently incorporated in proteins and nucleic acid, which provides framework for chloroplast, mitochondria and other structure in which the most of the biochemical reactions occur. Simultaneously, GA_3 application might have caused more cell division and cell elongation, thereby increasing the vegetative growth in strawberry (Singh and Singh 2009). Due to application of inorganic fertilizers and bio-fertilizers along with organic manures increased the available NPK status, organic C and microbial biomass and dehydrogenase activity and hence they help in increasing height and spread of the plant (Hazarika 2011).

Similarly, maximum number of leaves/plant (26.85) and leaf area/plant (128.78 cm^2) were recorded in T_{10}. Higher number of leaves and leaf area might be due to higher cell division caused by cytokinins and also due to higher supply of assimilate mediated by BA application (Dwivedi *et al*. 1999) besides, increase in the root surface to volume ratio, hormonal levels and photosynthetic rate due to the application of N fixing bacteria along with BA (Singh and Singh 2009).

Different treatment combinations have positive effect on runners/plant, duration of flowering and duration of fruiting. The runners/plant (7.45) was found maximum in T_{11}. Berry set (86.50%) and yield (113.85 q/ha) were also found maximum with this treatment. This increased berry set and yield may be due to the fact that N-fixer not only increased the availability of N to the plant roots but also increased their translocation from roots to flower through plant foliage. Simultaneously, synthesis of bio-regulator and exogenous application of GA_3 shifted the endogenous balance between promoters and inhibitors in favour of fruit forming processes (Sharma and Sharma 2006).

It is also evident from the data given in Table 2 that the maximum berry length (46.59 mm), diameter (29.62 mm) and weight (18.39 g) were obtained when plants were inoculated with 75% or 50% of RDF along with *Azospirillum,* PSB, 50% GA_3 and 50% BA. Berry size and weight are highly correlated with the 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), as well as favour synthesis of different growth regulators (Awasthi *et al*. 1998), exogenous application of GA_3 make the balance between inhibitors and promoters (Singh and Singh 2009). The increased number of berries/plant (28.77) and ultimately yield may also be due to the fact that the enhanced level of nutrients and auxins due to *Azospirillum* from the integration of nutrients could have diverted photoassimilates to the developing flower buds and helped in the conversion of flowers to more femaleness to produce higher number of fruits which in turn also increased the berry weight and yield. This is in agreement with findings of Chandra and Shivraj (1972).

Table 2 Effect of bio-fertilizers and bio-regulators on yield attributing characters and yield of strawberry cv. Festival

Treatment	Berry set (%)	Berry length (mm)	Berry diameter (mm)	Berry weight (g)	Berries/ plant	Yield (q/ha)
T_1	77.45	39.12	23.52	11.85	19.67	88.60
T_2	78.86	43.74	25.75	12.95	23.37	93.30
T_3	77.67	44.05	26.66	14.39	23.50	94.36
T_4	80.02	43.73	27.58	12.55	23.57	95.15
T_5	80.40	40.50	24.76	12.53	25.40	94.76
T_6	83.23	41.05	24.93	15.87	26.07	96.84
T_7	82.10	43.03	24.72	17.72	26.60	97.70
T_8	82.20	43.72	28.55	16.62	27.55	104.82
T_9	84.65	43.20	28.63	17.77	28.27	106.11
T_{10}	85.95	46.59	29.62	17.93	28.37	110.40
T_{11}	86.50	45.08	28.85	18.39	28.77	113.85
T_{12}	76.07	37.72	24.35	10.92	18.82	86.47
CD (P=0.05)	2.94	1.32	0.97	0.87	0.77	4.17

The yield and yield attributing characters mainly depend on growth characters of the plant. Greater accumulation of dry matter conferred greater ability to produce higher yield. The highest berry weight and yield in treatment T_{11} having 75 % RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA_3+ 50 ppm BA was due to vigorous plant growth characters. In this treatment, increased number of leaves might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher amount of carbohydrate could have promoted the growth rate and in turn increased the berry weight. The increased yield might also be due to more absorption and utilization of nutrients due to integrated use of organic and inorganic fertilizers along with bio-fertilizers. Similar increase in yield was also reported by Chezhiyan *et al*. (1999).

An inquisition of data presented in Table 3 revealed that combination of bio-fertilizers and bio-regulators with RDF have significant role on chemical composition of berry in terms of TSS, total sugar and ascorbic acid. The maximum TSS (9.26 %), total sugars(8.93%), ascorbic acid (65.67 mg/ 100g) were recorded in plants of T_{11}. The application of nitrogen fixing bacteria and GA_3 with lower dose of nitrogen might have exhibited regulatory role on the absorption and translocation of various metabolites, in which carbohydrates are most important which affects the quality of fruits. During ripening of fruits, the carbohydrates reserves of the root and stem are drawn upon heavily and hydrolysed into sugar. Terry *et al*. (2000) reported the increased translocation of assimilates from leaves to the developing fruits. Quality characters are highly correlated with the dry matter content and endogenous levels of hormones and the *Azospirillum* and PSB are known to favour the synthesis of different growth regulators like IAA, GA and

Table 3 Effect of bio-fertilizers and bio-regulators on quality parameters of quality parameters of strawberry cv. Festival

Treatment	TSS (°Brix)	Acidity (%)	Total sugar (%)	Non-reducing sugar (%)	Reducing sugar (%)	Ascorbic acid (%)
T_1	7.95	0.835	8.13	4.30	3.82	53.60
T_2	7.83	0.837	8.17	4.32	3.84	57.21
T_3	7.96	0.839	8.48	4.44	4.04	57.69
T_4	8.61	0.835	8.52	4.53	3.99	59.07
T_5	8.71	0.835	8.49	4.45	4.04	55.86
T_6	9.09	0.836	8.19	4.34	3.85	56.80
T_7	8.28	0.834	8.21	4.33	3.88	56.93
T_8	8.29	0.831	8.24	4.56	3.74	63.16
T_9	8.68	0.829	8.65	4.75	3.90	60.52
T_{10}	9.20	0.831	8.61	4.65	3.96	63.40
T_{11}	9.26	0.830	8.93	4.72	4.20	65.67
T_{12}	7.90	0.838	7.91	4.09	3.82	54.21
CD (P=0.05)	0.20	0.007	0.30	0.14	NS	1.12

cytokinins (Awasthi *et al.* 1998) and accumulation of dry matter (Wange 1996).

The increase in TSS content with combined use of bio-fertilizers along with NPK, organic manures and bio-regulators might be due to accumulation of sugars and other soluble components from hydrolysis of protein and oxidation of ascorbic acid. This finding corroborates with the findings of Rathi and Bist (2004) and Dey *et al*. (2005). The increase in total sugar in these treatments could be attributed due to quick metabolic transformation of soluble compounds and more conversion of organic acid into sugar. The increase in sugar content might be also due to the degradation of polysaccharides into monosaccharides. The lowest acidity with combination of RDF with *Azospirillum* and PSB along with GA_3 and BA could be attributed to dilution effect because of increased fruit size and conversion of acid in to sugar and salts. Similar result was also observed by Singh *et al*. (1996) in banana.

The estimates for correlation co-efficient for plant height, plant spread, leaf no., leaf area, crowns/plant, showed highly significant positive correlation with yield (Table 4). Plant height (r = 0.885**), plant spread (r = 0.778**), leaf no., (r = 0.860**), leaf area (r = 0.825**) and

Table 4 Correlation coefficient values of growth and yield attributing characters with yield

	Plant height	Plant spread	Leaf no.	Leaf area	Crowns/ plant	Yield (q/ha)
Plant height	1	0.807**	0.845**	0.828**	0.850**	0.885**
Plant spread		1	0.795**	0.567**	0.911**	0.778**
Leaf no.			1	0.710**	0.814**	0.860**
Leaf area				1	0.640**	0.825**
Crowns/plant					1	0.850**
Yield (q/ha)						1

Table 5 Correlation coefficient of yield attributing characters and morphological characters of berries with Yield

	Berry set (%)	Berry length (mm)	Berry diameter (mm)	Berry weight	Berries/ plant	Yield (q/ha)
Berry set (%)	1	0.668**	0.711**	0.893**	0.927**	0.931**
Berry length (mm)		1	0.832**	0.700**	0.744**	0.778**
Berry diameter (mm)			1	0.661**	0.724**	0.862**
Berry weight				1	0.907**	0.887**
Berries/plant					1	0.912**
Yield (q/ha)						1

crowns/plant (r = 0.850**) showed highly positive correlation among these parameters. Similarly, yield was also positively correlated with yield attributing characters as well as morphological characters of berries, viz. per cent berry set, berry length, berry diameter, berry weight, berries/ plant (Table 5). The per cent berry set (r = 0.931**), berry length (r = 0.778**), berry diameter (r = 0.862**), berry weight (r = 0.887**) and berries/plant (r = 0.912**) were positively correlated with yield and effect was found to be highly significant for all the parameters.

Our studies indicated that 'Festival' strawberry plants exhibit superiority in growth, yield attributing characters and yield when incorporated with 75 % RDF + vermicompost + *Azospirillum* + PSB + 50 ppm GA_3+ 50 ppm BA in Mizoram conditions of India. The quality parameters of the fruit also influenced by combined use of organic, inorganic and biological sources of nutrients.

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