www.hortflorajournal.com ICV: 4.79

HortFlora Research Spectrum, **2(4): 329-334 (Oct.-Dec. 2013)** **ISSN : 2250-2823**

EFFECT OF BIO-INOCULANTS ON LEAF NUTRIENT STATUS OF APPLE CV. RED DELICIOUS

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ABSTRACT: Significant differences were recorded for total leaf nitrogen, phosphorous and potassium in response to the different fertilizers treatments. The effect of fertilizer regimes on leaf nitrogen resulted in significant difference in which treatment F_1 recorded maximum leaf nitrogen (2.04 %) followed by F_3 (1.99 %) and F_4 (1.95 %). The interaction effect of phosphate solublizing inoculants and nitrogen fixing inoculants on leaf nitrogen recorded significant increase. However, there was non-significant differences in leaf phosphate and potassium in response to these two inoulants. Significant results were recorded in response to interaction effect of nitrogen fixing inoculants and fertilizer regimes. Effect of nitrogen fixing inoculants, phosphate solublizing inoculants and fertilizer regimes recorded a significant increase in leaf nitrogen.

Keywords: *Apple, bio-inoculants, leaf nutrients, fertilizer regime.*

Apple accounts for 52 per cent of total area and 75 per cent of total production of temperate fruits in India. The productivity in India has increased from 4.12 to 10.28 MT/ha over the last 25 years (Anon., 3). Though average productivity of apple in the state is highest at national level (10.34 t/ha), but at global level this position is deplorable. Among various factors which affect the productivity and cost of production, nutrition is the most important, which shares 30 per cent of total cost of production.

Most of the fertilizers which are applied to boost the production are lost through denitrification, leaching and fixation in soil. Fifty per cent of the nitrogenous fertilizer applied to crops is lost, Loss of fertilizer-N into the environment disturbs the balance (Prasad and Katyal, 13). It also makes ground water unsafe for drinking (Katyal and Buresh, 9; Venkitaswamy *et al.*, 15). In case of phosphatic fertilizers applied to plants only a small fraction (10-15%) are taken up by the plant in the years of application (Brady and Weil, 5).

Keeping all above points in view, use of bio-inoculants offer a better alternative for increasing the fertilizer use efficiency of applied fertilizers by enhancing the active root surface and soil fertility by atmospheric nitrogen fixation, solubilizing the fixed phosphorus in soil and by fastening the mineralization rate of organic manures and maintaining the sustainability of soil. Thus, the evaluation of different bio-inoculants under different fertilization regimes is urgently required in apple, for improving fertilizer use efficiency, yield, and quality under a cost effective sustainable production system. Keeping in view the above facts, the present investigation was carried out to study the effect of bio-inoculants on nutrient use efficiency of apple.

MATERIALS AND METHODS

The present investigation was conducted at the experimental farm of Division of Pomology, SKUAST-K, Shalimar. Four bio-inoculants of which two Phosphate solublizing inoculants [Phosphate solublizing bacteria (P_1) and Vesicular arbuscular mycorrhizae (P_2) i.e. *Glomus fasciculatum]* and two Nitrogen fixing inoculants [*Azotobacter chroococcum* (N_1) and *Azospirillum brasilense* (N_2)] were tested under four fertilizer regimes [75% NPK through chemical fertilizers +

Received : 20.08.2013 *Accepted : 22.09.2013*

25% NPK through organic manures (F_1), 50% NPK through chemical fertilizers + 25% NPK through organic manures (F_2), 25% NPK through chemical fertilizers + 75% NPK through organic manures (F_3) and 25% NPK through chemical fertilizers + 50% NPK through organic manures (F_4) and control (F_5) (i.e. recommended dose of NPK) on one of the most popular variety of apple i.e. Red Delicious. Bio-inoculants (lignite based) were obtained from Microbiology Centre, Division of Environmental Sciences, SKUAST-K, Shalimar.

The trees of uniform size and vigour of Red Delicious cultivar grafted on seedling rootstock with age of 15 years were selected. The experimental trees were inoculated with bio inoculants (lignite based) in the 1st week of April. The bio-inoculants were applied to the root zone. FYM was applied to the trees according to the treatment combination during the month of February. Nitrogen was applied as urea, phosphorus as di-ammonium phosphate (DAP) and potassium as muriate of potash (MOP). Full dose of DAP and MOP and half dose of urea was applied during March, whereas, remaining urea was split into two equal doses and were applied fifteen days after fruit set and next in July.

Leaf samples were collected from the middle of current season's growth during 1st week of August. Cleaning, drying, grinding and storage of samples were carried out in accordance with the standard procedure. Samples were digested for estimation of nitrogen through concentrated sulphuric acid by adding digestion mixture as described by Jackson (7). For the estimation of phosphorus and potassium, samples were digested in di-acid mixture prepared by mixing nitric acid and per-chloric acid in the ratio of 4:1 (Piper, 12). Total nitrogen was determined by micro-Kjeldhal's method (AOAC, 1), whereas, total phosphorus was determined by Vanadomolybdo phosphoric yellow colour method (Jackson, 7) and total potassium was determined by flame photometer. The estimated nutrients were expressed as per cent on dry weight basis.

RESULTS AND DISCUSSION

Total leaf nitrogen (%)

Significant differences were recorded for total leaf nitrogen in response to the effect of nitrogen fixing inoculants (Table 1). Treatment N_1 (*Azotobacter*) resulted in maximum leaf nitrogen (2.05%). Whereas, the effect of phosphate solublizing inoculants on leaf nitrogen recorded non-significant effect. However, treatment P_1 (PSB) recorded maximum leaf nitrogen (1.99%). The effect of fertilizer regimes on leaf nitrogen resulted in significant difference. Treatment F_1 recorded maximum leaf nitrogen (2.04 %) followed by F_3 (1.99 %) and F_4 (1.95 %). Minimum leaf nitrogen was observed in treatment F_2 (1.88 %). However, treatments F_2, F_3 and F_4 were found to be statistically at par.

Total leaf phosphorus (%)

Perusal of the data (Table 1) revealed that leaf phosphate recorded non-significant response with nitrogen fixing inoculants. However, treatment N_1 (*Azotobacter*) recorded the maximum value (0.121 %). Similarly, non-significant differences in leaf phosphate were recorded in response to phosphate solublizing inoculants. However, treatment P_2 (VAM) recorded maximum value (0.119%). Effect of fertilizer regimes also recorded a non-significant difference in leaf phosphate. However, treatment F_3 recorded maximum value (0.123 %) followed by F_1 (0.121 %).

Total leaf potassium (%)

Non-significant differences in leaf potassium (Table 1) were observed in response to nitrogen fixing inoculants. However, treatment N_1 (*Azotobacter*) recorded higher value (0.88%). Similarly, effect of phosphate solublizing inoculants recorded non-significant increase in leaf potassium, whereas, P_2 (VAM) recorded maximum leaf potassium (0.88 %). Non-significant results were obtained in response to effect of fertilizer regimes. However, treatment F_1 recorded the maximum leaf potassium (0.91%).

Interaction effects

The interaction effect of phosphate solublizing inoculants and nitrogen fixing inoculants on leaf nitrogen recorded significant increase (Fig. 1). Treatment P_2N_1 recorded maximum value (2.13 %) followed by treatments P_1N_1 (1.97 %) and P_2N_2 (1.92 %). Minimum leaf nitrogen was recorded in treatment P_1N_2 (1.84 %). However, treatments P_1N_2 and P_2N_2 were found to be statistically at par. Significant results were recorded in response to interaction effect of nitrogen fixing inoculants and fertilizer regimes (Fig. 2). Treatment F_1N_1 recorded highest value (2.23%) followed by F_3N_1 (2.06 %), F_4N_1 (2.00%), F_3N_2 (1.92 %). Minimum leaf nitrogen was recorded in treatment F_1N_2 (1.85 %). However, treatments F_1N_2, F_2N_1, F_2N_2, F_3N_2, F_4N_1 and F_4N_2 were found to be statistically at par.

Non-significant results were obtained in response to interaction effect of phosphate solublizing inoculants and fertilizer regimes (Fig. 3). However, treatment F_1P_2 recorded maximum leaf nitrogen (2.06 %). On the contrary, the interaction effect of nitrogen fixing inoculants, phosphate solublizing inoculants and fertilizer regimes recorded a significant increase in leaf nitrogen (Table 2). Treatment $F_1P_2N_1$ recorded maximum leaf nitrogen (2.37 %) followed by $F_1P_1N_1$ (2.31 %), $F_3P_2N_1$ (2.27 %), $F_1P_2N_1$ (2.15 %), $F_3P_1N_1$ (2.11 %). Minimum leaf nitrogen was recorded in treatments $F_4P_2N_1$ (1.73 %). However, treatments $F_1P_1N_2$, $F_2P_1N_1$, $F_2P_1N_2$, $F_2P_2N_2$, $F_3P_2N_2$, $F_4P_1N_2$, $F_4P_2N_1$ were found to be statistically at par with each other.

Non-significant results were obtained in response to interaction effect of phosphate solublizing inoculants and nitrogen fixing inoculants (Fig. 1). However, treatment P_2N_1 recorded the maximum value (0.122 %) followed by P_1N_2 (0.119 %). Similarly, effect of nitrogen fixing inoculants and fertilizer regimes also resulted in non-significant increase in leaf phosphate (Fig. 2). However, treatment F_3N_1 recorded the maximum value (0.126 %) followed by F_4N_1 (0.124 %). The effect of phosphate solublizing inoculants and fertilizer regimes also resulted in non-significant differences in leaf phosphate (Fig. 3). However, treatment F_3P_2 recorded the maximum value (0.129%) followed by F_3P_1 (0.124%). Non-significant results were obtained in response to interaction effect of nitrogen fixing inoculants, phosphate solublizing inoculants and fertilizer regimes (Table 2). However, treatment $F_3P_2N_1$ recorded the maximum value (0.129 %) followed by $F_1P_2N_1$ (0.128 %). The values obtained ranged from 0.111 per cent in F_5 to 0.129 per cent in $F_3P_2N_1$.

Interaction of phosphate solublizing inoculants and nitrogen fixing inoculants recorded non-significant effect on leaf potassium (Fig. 1). However, treatment P_2N_1 recorded maximum value (0.90 %). Similarly, interaction of nitrogen fixing inoculants and fertilizer regimes also recorded non-significant differences in leaf potassium (Fig. 2). However, treatment F_1N_1 recorded maximum value (0.94 %) followed by F_3N_1 (0.92 %) and F_4N_1 (0.88 %). Leaf potassium recorded non-significant differences in response to interaction of phosphate solublizing inoculants and fertilizer regimes. However, maximum value was recorded in treatments F_1P_2 and F_4P_2 both (0.95 %). Whereas, leaf potassium recorded significant differences in response to interaction of nitrogen fixing inoculants, phosphate solublizing inoculants and fertilizer regimes (Table 2). Treatment $F_1P_2N_1$ recorded maximum leaf potassium (1.08 %) followed by treatments $F_4P_2N_2$ (1.04 %), F_5 (0.97 %), $F_2P_1N_1$ (0.95 %), $F_3P_2N_2$ (0.92 %). Whereas, minimum value was recorded in treatment $F_3P_1N_2$ (0.63 %).

Leaf nutrient status

Studies revealed that nitrogen content of leaf was maximum (2.37%) with treatment $F_1P_2N_1$ followed by $F_1P_1N_1$ (2.31%), whereas, treatment $F_4P_2N_1$ recorded minimum (1.73%) nitrogen content (Table 2). Higher leaf nitrogen content might have resulted from higher and balanced

Table 1: Effect of different source of nutrient fertilizer on leaf NPK.

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	2.05	0.121	0.88
T_2	1.88	0.119	0.83
T_3	1.99	0.118	0.82
T_4	1.95	0.119	0.88
T_5	2.04	0.121	0.91
T_6	1.88	0.112	0.85
T_7	1.99	0.123	0.81
T_8	1.95	0.121	0.85

T_1-Azotobacter, T_2-Azospirillum, T_3-PSB, T_4-VAM, T_5-75%NPK as chemical fertilizer +25% NPK as OM, T_6-50%NPK as chemical fertilizer +25%NPK as OM, T_7-25%NPK as chemical fertilizer +75%NPK as OM, T_8-25%NPK as chemical fertilizer +50%NPK as OM

Table 2: Interaction effect of nitrogen fixing inoculants, phosphate solublizing inoculants and fertilizer regimes on leaf N P K.

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)
$F_1P_1N_1$	2.31	0.114	0.76
$F_1P_1N_2$	1.81	0.113	0.86
$F_1P_2N_1$	2.37	0.128	1.08
$F_1P_2N_2$	1.97	0.126	0.85
$F_2P_1N_1$	1.82	0.114	0.95
$F_2P_1N_2$	1.86	0.114	0.83
$F_2P_2N_1$	2.00	0.105	0.79
$F_2P_2N_2$	1.86	0.114	0.82
$F_3P_1N_1$	2.11	0.123	0.83
$F_3P_1N_2$	1.96	0.125	0.63
$F_3P_2N_1$	2.27	0.129	0.85
$F_3P_2N_2$	1.87	0.116	0.92
$F_4P_1N_1$	2.00	0.122	0.88
$F_4P_1N_2$	1.81	0.123	0.70
$F_4P_2N_1$	1.73	0.125	0.87
$F_4P_2N_2$	1.99	0.113	1.04
F_5 (Control)	2.15	0.111	0.97
LSD(0.05)	**0.23**	**NS**	**0.20**

uptake of nitrogen by plant roots from readily available nitrogen in chemical fertilizer. Since *Azotobacter* is known to fix atmospheric nitrogen, *vis-à-vis Azotobacter* and VAM are known to secrete plant growth substances. These might had caused vigorous root growth leading to more root area for root colonization with VAM resulting in increased nutrient uptake.

The results obtained are in line with findings of Godara *et al.* (6) who observed higher leaf nitrogen content of peach seedlings applied with receiving inorganic nitrogenous and phosphatic fertilizers alongwith dual inoculation of VAM and *Azotobacter*. Marathe and Bharambe (10) observed maximum leaf nitrogen in treatments receiving FYM (to supply 50% nitrogen) + 50 per cent recommended dose of fertilizers. Karlidag *et al.* (8) reported significantly higher leaf nitrogen content in apple leaves inoculated with plant growth promoting rhizobacteria than the non-inoculated ones.

Maximum leaf phosphorus (0.129%) was recorded in treatment $F_3P_2N_1$ followed by $F_1P_2N_1$ (0.128%). Minimum leaf phosphorus (0.111%) was recorded under treatment F_5. Godara *et al.* (6) reported higher leaf phosphorus in treatments receiving inorganic fertilizers alongwith dual inoculation of VAM and *Azotobacter*. Marathe and Bharambe (10) observed higher leaf phosphorus in treatments receiving FYM (to supply 50% N) + 50 per cent recommended dose of fertilizers. Sharma *et al.* (14) observed maximum leaf phosphorus content in apple with inoculation of *Glomus macrocarpum* supplemented with 50 ppm phosphorus in soil. Higher leaf phosphorus content under VAM applied treatments may be attributed to the increased phosphatase activity and enhanced surface area of roots which resulted in higher uptake of nutrients.

Studies revealed that maximum leaf potassium content (1.08 %) was observed in treatment $F_1P_2N_1$ followed by treatment $F_4P_2N_2$ (1.04 %). Minimum leaf potassium (0.70 %) was observed in treatment $F_4P_1N_2$. The results obtained are in confirmation

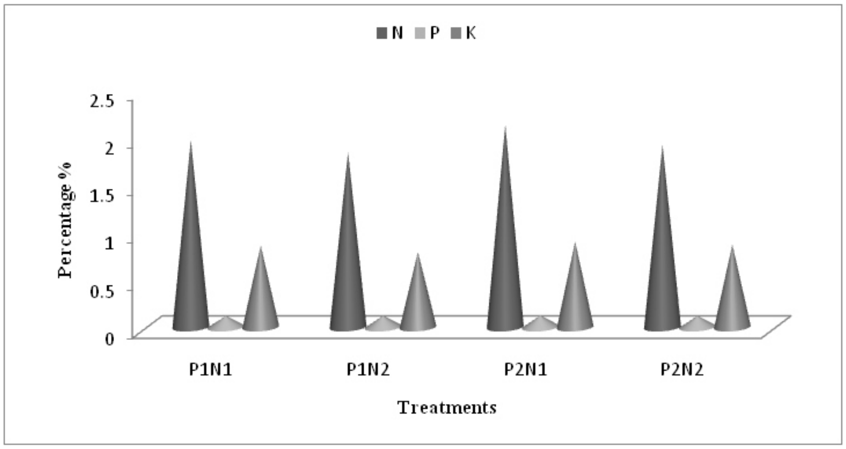

Fig. 1 : Interaction effect of nitrogen fixing inoculants and phosphate solublizing inoculants on leaf NPK in apple cv. Red Delicious.

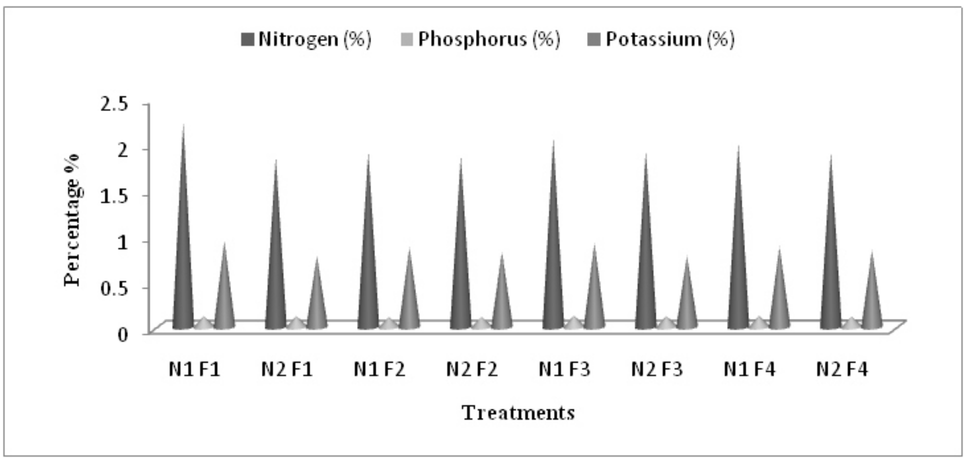

Fig. 2 : Interaction effect of nitrogen fixing inoculants and fertilizer regimes on leaf NPK in apple cv. Red Delicious.

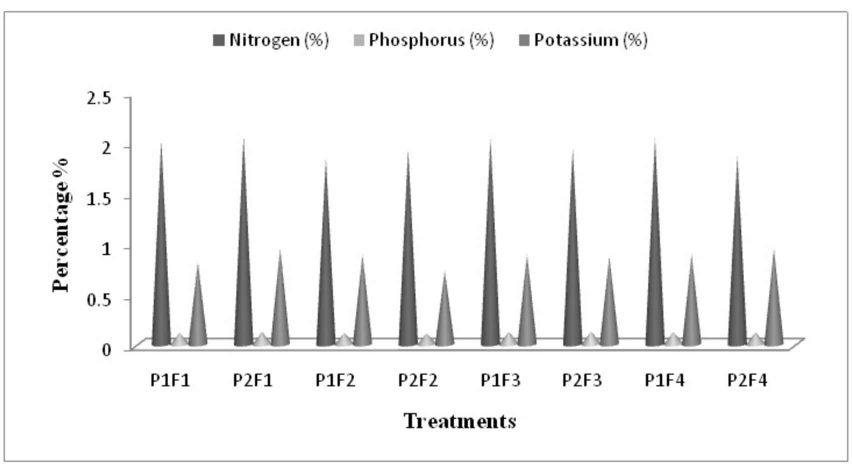

Fig. 3 : Interaction effect of phosphate solubilizing inoculants and fertilizer regimes on leaf NPK in apple cv. Red Delicious.

with the findings of Godara *et al.* (6) who found highest leaf potassium with dual inoculation of *Azotobacter* and VAM with no fertilizer application. However, Aseri and Rao (4) reported higher leaf potassium with dual inoculation of *Azotobacter* and VAM. Marathe and Bharambe (10) observed maximum leaf potassium with the application of FYM (to supply 50% N) + 50 per cent recommended dose of fertilizers. The increase in potassium content could be attributed to the increased dissolution of fixed forms, mobilization and uptake of soil potassium, primarily by increasing absorption by mycorrhizal hyphae in avocado has been reported by Menege *et al.* (11).

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