The Stimulatory Effects of Humic Substances and Microbial Inoculants on Cropping Performance of Guava (*Psidium guajava* L.) cv. Lalit in Meadow Orcharding System †

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Abstract: Foliar application of humic acid along with bio-inoculants in 4-year-old inarched guava cv. Lalit in meadow orcharding system was carried out. Foliar application of humic acid @ 30 and 60 mL/L at bud burst to flowering stage and bio-inoculants (Phosphorus solubilizing bacteria (PSB) @ 10 mL/plant + Azotobacter chroococcum @ 10 g/plant, and PGPR @ 25 mL/plant + AM fungi @ 25 g/plant) in rhizosphere along with @ 90 and 80 percent of the recommended dose of fertilizers (RDF) of NPK (360:740:200 g/tree) was carried out. Application of humic acid applied at 60 mL/L along with PSB and A. chroococcum at 10 mL/plant beside 80 per cent of RDF-NPK inferred positive impact on growth traits throughout the winter season. This combination recorded vital increase in percent fruit set with reduced fruit drop. Fruit yield was 2.9 times higher over control. Fruit quality with this conjoint application also improved. Soil microflora recorded as actinomycetes, A. chroococcum, PSB and AM fungi were improved. This combination also exhibited significant increase in leaf N, P and K contents in the meadow geometry plant–soil interface. Maximum cumulative variance of 97.9 percent in PCA based on the Eigenvalue (>1) was recorded. Maximum total cumulative variance for vegetative growth characteristics, flowering and yield contributing traits in guava under meadow plantations were observed in PC4. Our findings emphasized the promising effects of humic acid and bio-inoculants on improvement of growth, nutrient profiling and biological activity at reduced application of NPK.

Keywords: bio-inoculants; rhizosphere; humic substances; crop geometry

1. Introduction

Guava (*Psidium guajava* L.), the poor man’s fruit, is synonymous to the apple of the tropics, and is an appetizing, nutritionally valuable and remunerative fruit crop. The crop has excelled with relevance to favorable growing factors (productivity, hardiness and antioxidant content). The cultivar Lalit is one of the most widespread and high-quality cultivars available for guava farmers. The crop detaches among other tropical fruits for its taste, mineral composition, high lycopene content and possibilities of consumption, attributes that guarantee preference for different consumer markets worldwide. Meadow orcharding is a new concept of guava cultivation, managing dwarf tree canopy with
modified pruning at highly closer spacing of 2 m (row to row) \( \times \) 1.5 m (plant to plant), which gives a density of 3333 plants/ha. Traditional planting at 6 \( \times \) 6 m spacing has exhibited issues of low levels of productivity because of massive tree cover. Meadow orcharding is an embellished technique of fruit cultivation with changed tree cover, promoting the accrued rate of chemical change that ends up in high yield per unit space. The orcharding system utilizes small and dwarf trees with modified canopy architecture and growth regulation by the training and pruning. This technique of planting has revolutionized the guava trade, which boosts productivity including the reduction in cost of production. Humic acid, the moist and dark complex fraction, is the most active part of soil organic matter (SOM), which accounts for 60 per cent of the soil, and is the cause of many advanced chemical reactions in soil [1]. The effects of humic acid compounds have been attributed to improvements in physical, chemical and biological conditions of the soil. The bio-inoculants are cost effective and are renewable supplier of nutrients and thrive with symbiotic association with microbial strains that enhance productivity by (i) stimulating the biological organic processes, (ii) promoting the solubilization of insoluble phosphates in soil, (iii) activating plant growth vitamins and (iv) channeling alternative growth regulating substances needed essentially for plant growth and development [2]. This study was carried out with the prime objective to evaluate the synergistic effect of foliar application of humic acid and microbial inoculants on cropping behavior in guava (*Psidium guajava* L.) under meadow orcharding.

2. Materials and Methods

The study was carried out at the Regional Horticultural Research and Training Station of the Dr YS Parmar University of Horticulture and Forestry at Dhaulakuan, Sirmour, Himachal Pradesh, India (Geographical coordinates: 35.5° N latitude, 77.5° E longitude, 468 m above mean sea level). The area experienced sub-tropical, sub-montane and low hill climatic conditions. Trees were selected based on similarities in their growth pattern to minimize variability caused by differences in tree size. The experimental manipulations used were three rows north to south to optimize effective light interception with lower air temperature and humidity. Four-year-old inarched guava trees of cultivar ‘Lalit’, spaced at 2 m \( \times \) 1.5 m under the meadow planting system, were selected which received all usual scientific horticultural care. Different fertilizer inputs, i.e., humic acid, PSB, *A. chroococcum*, PGPR and AM fungi, were included. Humic acid (foliar spray) was supplemented at two levels during winter season at bud burst to flowering stage i.e., HA\(_{30}\)-30 mL/L and HA\(_{60}\)-60 mL/L. Microbial inoculants were applied to the rhizosphere at B\(_1\): PSB @10 mL/plant + *A. chroococcum* @ 10 g/plant and B\(_2\): PGPR @ 25 mL/plant + AM fungi @ 25 g/plant, along with reduced levels of RDF of NPK (360:740:200 g/tree) i.e., 90 percent of RDF (NPK\(_{90}\)) and 80 percent of RDF(NPK\(_{80}\)). The experiment was designed in randomized complete block design with eight treatment combinations along with a control with three replications (three trees per treatment). The treatments comprised of combinations; B\(_1\)HA\(_{30}\)NPK\(_{90}\), B\(_2\)HA\(_{30}\)NPK\(_{90}\), B\(_1\)HA\(_{60}\)NPK\(_{90}\), B\(_2\)HA\(_{60}\)NPK\(_{90}\), B\(_1\)HA\(_{30}\)NPK\(_{80}\), B\(_2\)HA\(_{30}\)NPK\(_{80}\), B\(_1\)HA\(_{60}\)NPK\(_{80}\), B\(_2\)HA\(_{60}\)NPK\(_{80}\) and Control.

Vegetative growth traits including plant height and girth of guava trees were recorded during the month of November and means were compared using standard errors. Five uniform and healthy shoots from one-year-old shoots from the current season’s growth in all four directions were selected randomly for measuring shoot growth and the values were expressed in centimeter (cm). The trunk circumference measured at 10 cm above the graft union using a measuring tape was recorded. Length of flowering was calculated at the beginning of the vegetation period in the trees. In order to investigate the effect of treatments on fruit set and drop, the duration of flowering was counted. Fruit set was determined as the percent of fruits per total remaining flowers. Fruit yield of the trees was recorded on each commercial harvest in kg/tree. Yield efficiency in terms of TCSA and TCV was calculated using trunk circumference and canopy volume. Fruit samples at full physiological maturity stage during the period of February–March were harvested.
and bio-chemical analysis was carried out for fruit quality characteristics using standard methods. Total soluble solids (TSS) were evaluated at 25 ± 2 °C of all sampled fruits at consumer maturity with a hand refractometer in °Brix.

3. Results and Discussion

3.1. Growth Indices

Foliar application of humic acid and microbial inoculants are positively related to increase agro-morphometric traits, flowering behavior, fruit yield, nutrient content of soil and leaf during winter season (Table 1). The data showed that growth characteristics including, plant height, trunk girth, canopy diameter and shoot growth had noticeable improvement with respect to the application of humic acid and bio-inoculants along with inorganic fertilizers when supplemented to the trees under meadow orcharding. Enhanced N and P uptake was also positively correlated due to humic acid application with better vegetative growth in plants [3]. Humic acid promotes plant growth by stimulating IAA activity, which has increased H⁺ pump through plasma membrane, lowers cell wall pH and initiates cell wall loosening and expansion process. Besides, the improved uptake of micronutrients with humic acid application enhanced plant growth traits [4]. Humic acid being major component of organic matter in soil increases the plant height through improving photosynthesis rate, respiration, root growth, soil fertility and nutrient elements uptake.

Table 1. Growth traits influenced by humic acid and bio-inoculants in meadow guava cv. Lalit.

| Treatment                  | Plant Height (cm) | Trunk Girth (cm) | Canopy Diameter (cm) | Shoot Growth (cm) |
|----------------------------|-------------------|------------------|----------------------|-------------------|
| B₁HA₃₀NPK₈₀                | 219.1 ± 2.3 g     | 21.2 ± 2.3 h     | 214.2 ± 2.2 h        | 11.2 ± 2.2 g      |
| B₂HA₃₀NPK₈₀                | 221.8 ± 2.8 e     | 24.2 ± 2.3 e     | 216.1 ± 2.4 f        | 13.1 ± 1.1 f      |
| B₁HA₆₀NPK₈₀                | 234.2 ± 2.6 b     | 27.2 ± 2.3 b     | 218.3 ± 2.2 c        | 15.6 ± 0.9 c      |
| B₂HA₆₀NPK₈₀                | 221.9 ± 2.6 e     | 22.9 ± 2.4 f     | 216.7 ± 2.0 e        | 13.5 ± 1.1 e      |
| B₁HA₃₀NPK₆₀                | 223.9 ± 2.4 d     | 26.1 ± 2.2 d     | 219.2 ± 2.3 b        | 15.9 ± 1.3 b      |
| B₂HA₃₀NPK₆₀                | 219.6 ± 2.3 f     | 21.9 ± 2.5 g     | 215.1 ± 2.2 g        | 13.13 ± 1.9 f     |
| B₁HA₆₀NPK₆₀                | 235.3 ± 2.3 a     | 28.1 ± 2.3 a     | 220.3 ± 2.3 a        | 16.4 ± 1.1 a      |
| B₂HA₆₀NPK₆₀                | 232.7 ± 2.4 c     | 26.7 ± 2.3 c     | 217.8 ± 2.6 d        | 15.1 ± 1.0 d      |
| NPK (360:740:200)          | 205.9 ± 2.3 h     | 22.1 ± 2.6 g     | 195.5 ± 2.2 i        | 9.2 ± 1.2 h       |

HA₃₀, humic acid at 30 mL/L; HA₆₀, humic acid at 60 mL/L; bio-inoculants consortium (B₁) i.e., PSB at 10 mL/plant + A. chroococcum at 10 g/plant; bio-inoculants consortium (B₂) i.e., PGPR at 25 mL/L/plant + AM fungi at 25 g/plant. The values represent mean (±SEM) of three replicates. The values followed by the same letter within each column are not significantly different from each other according to DMRT (p ≤ 0.05).

3.2. Flowering and Fruiting

Application of 80 percent NPK significantly induced flowering and fruiting behavior of guava during the cropping period. Foliar sprays of humic acid application have several advantages for guava production. During winter season, the trees which were treated with B₁HA₆₀NPK₈₀ treatment combination recorded maximum increment in length of flowering shoot. Earlier literature has well established that NPK content and phyto-hormones, especially gibberellins in roots, increased flower bud formation [5]. The results obtained on fruit set and drop indicated that there were statistical differences among different treatments applied (Table 2). When the treatment combinations were compared based on average fruit set, the B₁HA₆₀NPK₈₀ treatment combination had relatively higher percent of fruit set (64.8%) followed by B₁HA₈₀NPK₉₀, B₁HA₃₀NPK₈₀ and B₂HA₆₀NPK₈₀ with corresponding values of 63.8, 62.9 and 62.51 percent, respectively. Fruit drop had tremendously decreased in guava trees (13.8%) when supplemented with B₁HA₆₀NPK₈₀ treatment combination, whereas, maximum fruit drop (21.2%) was noticed in control. Similarly, application of humic acid combined with A. chroococcum might have improved the fruit yield (Table 3) due to the role of bacteria in colonizing the rhizosphere, root surface and superficial intercellular spaces of plants, improving nutrient cycling through N fixation [6]. The use of humic acid results in the increased yield by stimulating photosynthesis [7]. Besides, it might influence
fruit yield through mineral solubilization and through atmospheric N fixation [8]. The improvement in plant growth and canopy via application of humic acid allows better light interception by the plant thus increasing yield [9]. The best yield efficiency indicated that the treatment of B1HA60NPK80 was recorded as the highest (1.3 kg/m² TCSA), which was further followed by B2HA60NPK90 (1.2 kg/m² TCSA), B1HA30NPK90 (1.2 kg/m² TCSA) and B1HA30NPK80 (1.1 kg/cm² TCSA), whereas it was lowest (0.9 kg/m²) in control. In guava trees, the highest FY/TCV (1.1 kg/m³ TCV) was recorded in B1HA60NPK80 and the lowest FY/TCV (0.5 kg/m³ TCV) was recorded in control (Table 3).

**Table 2.** Yield contributing traits of guava cv. Lalit under meadow plantation.

| Treatment       | Duration of Flowering (days) | Fruit Set (%) | Fruit Drop (%) |
|-----------------|------------------------------|---------------|---------------|
| B1HA30NPK90     | 40.5 ± 0.7 f                 | 57.9 ± 1.0 h  | 18.1 ± 0.5 b  |
| B2HA30NPK90     | 42.5 ± 1.4 b                 | 60.0 ± 0.8 f  | 16.8 ± 0.2 c  |
| B1HA40NPK90     | 41.2 ± 0.8 d                 | 63.8 ± 0.7 b  | 14.6 ± 0.3 g  |
| B2HA40NPK90     | 41.7 ± 0.9 c                 | 61.8 ± 0.8 e  | 16.1 ± 0.5 d  |
| B1HA30NPK80     | 40.6 ± 0.8 ef                | 62.9 ± 1.0 c  | 13.0 ± 0.1 h  |
| B2HA30NPK80     | 39.4 ± 1.4 g                 | 59.0 ± 1.1 g  | 15.6 ± 0.4 e  |
| B1HA40NPK80     | 38.3 ± 0.6 h                 | 64.8 ± 0.5 a  | 13.7 ± 0.2 h  |
| B2HA40NPK80     | 40.7 ± 1.1 e                 | 62.5 ± 0.9 d  | 14.8 ± 0.4 f  |
| N:P:K (360:740:200) | 45.2 ± 1.3 a     | 47.9 ± 0.8 i  | 21.2 ± 0.8 a  |

HA60, humic acid at 30 mL/L; HA40, humic acid at 60 mL/L; bio-inoculants consortium (B1), i.e., PSB at 10 mL/plant + A. chroococcum at 10 g/plant; bio-inoculants consortium (B2), i.e., PGPR at 25 mL/plant + AM fungi at 25 g/plant. The values represent mean (±SEM) of three replicates. The values followed by the same letter within each column are not significantly different from each other according to DMRT (p ≤ 0.05).

**Table 3.** Fruit yield (FY) and yield efficiency of guava cv. Lalit under meadow plantation.

| Treatment       | Fruit Yield (kg/tree) | Yield Efficiency |
|-----------------|-----------------------|------------------|
|                 | FY/TCSA (kg/cm²)      | FY/TCV (kg/m³)   |
| B1HA30NPK90     | 4.1 ± 0.1 h           | 1.2 ± 0.1 ab     | 0.7 ± 0.1 c   |
| B2HA30NPK90     | 4.3 ± 0.1 g           | 0.9 ± 0.1 c      | 0.8 ± 0.1 c   |
| B1HA40NPK90     | 5.5 ± 0.9 c           | 0.9 ± 0.1 c      | 0.9 ± 0.1 bc  |
| B2HA40NPK90     | 4.8 ± 0.1 e           | 1.2 ± 0.1 ab     | 0.8 ± 0.1 bc  |
| B1HA30NPK80     | 5.9 ± 0.1 b           | 1.1 ± 0.1 ab     | 1.0 ± 0.1 ab  |
| B2HA30NPK80     | 4.5 ± 0.1 f           | 1.0±0.1 bc       | 0.9 ± 0.1 c   |
| B1HA40NPK80     | 6.4 ± 0.1 a           | 1.3 ± 0.1 a      | 1.1 ± 0.1 a   |
| B2HA40NPK80     | 5.1 ± 0.1 d           | 1.1 ± 0.1 bc     | 0.8 ± 0.1 c   |
| N:P:K (360:740:200) | 2.2 ± 0.1 i         | 0.9 ± 0.1 c      | 0.5 ± 0.1 d   |

HA30, humic acid at 30 mL/L; HA40, humic acid at 60 mL/L; bio-inoculants consortium (B1), i.e., PSB at 10 mL/plant + A. chroococcum at 10 g/plant; bio-inoculants consortium (B2), i.e., PGPR at 25 mL/plant + AM fungi at 25 g/plant. The values represent mean (±SE) of three replicates. The values followed by the same letter within each column are not significantly different from each other according to DMRT (p ≤ 0.05).

### 3.3. Fruit Quality

The physical parameters of fruits especially, fruit dimension and fruit weight positively influenced by conjoint humic acid and bio-inoculants application in guava. The possible reason might be ascribed to improved agro-morphometric traits, which were improved on account of more carbohydrates accumulation and translocation of photosynthetic reserves in the fruitlets. The effect of humic acid on the enhancement of photosynthetic pigment accumulation and photosynthesis rate could explain the rise in fruit weight [10]. Besides, increased uptake of N also stimulated the catalytic activity and number of enzymes in the physiological processes, which increased sugars and amino acids production, and hence, bio-chemical characteristics of fruit samples were increased [11]. Furthermore, NPK utilized in metabolic processes for production of amino acids and amino sugars has converted complex forms into simple sugars, and thus, increased fruit quality traits.
3.4. Post Harvest Soil Chemical Indicators

Significant however negligible effect of foliar humic acid and microbial inoculants were observed especially soil reaction and electrical conductivity. Conjoint combinations humic substances and bio-inoculants at reduced inorganic NPK doses towards neutral. Soil organic carbon build up was recorded higher when trees were supplemented with B\textsubscript{1}HA\textsubscript{60}NPK\textsubscript{80}. This superior combination also showed maximum available NPK in the rhizosphere zone. The increase in pH, EC and OC levels in soil might be due to the breakdown of organic matter after the incorporation of both bio-inoculants and humic acid. Soil organic matter has been considered to be greatly responsible directly or indirectly for making the physical environment of soils favorable for growth of crops. \textit{A. chroococcum}, when applied, fixed the atmospheric nitrogen in soil due to its nitrogen fixing properties, while PSB was involved in increasing the availability of phosphorus in soil due to its solubilizing properties, and thus, compensated the reduced dose of NP, and in turn, maintained better soil environment, which ultimately reflected on fertility status of soil [12]. Humic acid is the main component of soil organic matter, which influences the soil parameters, including nutrient solubility by forming complex forms with chemical compounds of humic materials.

3.5. Leaf Nutrients

In the present study, foliar application of humic substances showed positive and significant effect on leaf NPK content. Earlier studies suggested that organic material solubilized the available nutrient pool in the soil, which might also be due to the production of organic acids, especially aspartic acid and alpha-ketoglutaric acids, which decrease the pH of soil and thereby increase nutrient uptake [13]. Other reason also ascribed to microbial action to increase root surface to volume ratio [11]. Humic acid increased nutrition intake especially leaf N, P and K content which might be related to the improved root growth and enhanced permeability of plant membranes thereby increasing plant growth [14]. The positive effect of humic substances also increased P recovery when interfered with calcium phosphate precipitation [15].

3.6. PCA Studies

Principle Component Analysis (PCA) was also worked out to identify the effect of humic acid and bio-inoculants on the vegetative and yield related traits. It summed up the correlation between the factor and the two illustrated axis of vegetative growth characters (plant height, trunk girth, canopy diameter and shoot growth), flowering and fruiting characters (length of flowering shoot, number of flower buds per shoot, duration of flowering, fruit set and fruit drop) and yield contributing traits (Table 4). The first components that accounted for the highest total variance based on the Eigenvalue (>1) were found by PCA studies and showed 84.8% (PC1), 92.7% (PC2), 96.1% (PC3) and 97.9% (PC4) of the cumulative variance. PC4 registered the highest overall cumulative variance among vegetative, generative and yield-related traits of guava under meadow orcharding. The PCA studies incorporated the variables with values that are equal to or greater than two-thirds of the value of highest variable within each PC. PCA was also used to determine the efficacy of humic acid and bio-inoculants on soil chemical properties and leaf nutrients (data not shown). The first components that further accounted for the highest total variance based on the Eigenvalue (>1) were found by PCA studies and showed 67.3% (PC1), 81.1% (PC2), 89.1% (PC3) and 95.4% (PC4) of the cumulative variance. The PCA biplots with original variables/factors drawn as ‘Eigenvectors’ depicted the correlation between the factor and the two illustrated axis of soil chemical properties (pH, EC and available NPK), soil microbiological properties (actinomycetes, \textit{A. chroococcum}, phosphorus solubilizing bacteria and AM fungi spores) and leaf nutrients (NPK). Furthermore, the maximum variance for PC1 was recorded as 67.3 percent, whereas PC4 recorded the minimum variance (6.1%). Similar hypothesis on PCA were also documented in strawberry [16], pistachio nut [17] and apple [18,19].
Table 4. PCA of growth traits, flowering and yield contributing parameters under meadow guava.

| Parameter                  | Principal Component |
|----------------------------|---------------------|
|                            | PC1 | PC2 | PC3 | PC4 |
| Eigenvalue                 | 13.6| 1.3 | 0.6 | 0.3 |
| Variability (%)            | 33.8| 7.9 | 3.4 | 1.8 |
| Cumulative variance (%)    | 84.8| 92.7| 96.1| 97.9|

| Variables                  | Factor Loadings (Pattern Matrix) | Vectors |
|----------------------------|----------------------------------|---------|
|                            | F1  | F2  | F3  | F4  | PC1 | PC2 | PC3 | PC4 |
| Plant height               | 0.9 | −0.2| 0.0 | 0.3 | 0.3 | −0.2| 0.0 | 0.5 |
| Trunk girth                | 0.8 | −0.5| 0.4 | 0.1 | 0.2 | −0.4| 0.5 | 0.1 |
| Canopy Diameter            | 0.9 | 0.1 | −0.3| 0.0 | 0.3 | 0.1 | −0.4| −0.1|
| Shoot growth               | 1.0 | −0.2| 0.1 | −0.1| 0.3 | −0.2| 0.1 | −0.2|
| Duration of flowering      | −0.8| −0.4| 0.1 | −0.1| −0.2| −0.4| 0.1 | −0.3|
| Fruit set                  | 1.0 | 0.0 | −0.2| 0.0 | 0.3 | 0.0 | −0.2| 0.0 |
| Fruit drop                 | −1.0| 0.0 | 0.0 | 0.2 | −0.3| 0.0 | 0.0 | 0.3 |
| Fruit yield                | 1.0 | 0.1 | 0.1 | −0.1| 0.3 | 0.0 | 0.1 | −0.2|
| YE (TCSA basis)            | 0.5 | 0.8 | 0.4 | 0.1 | 0.1 | 0.7 | 0.5 | 0.2 |
| YE (TCV basis)             | 1.0 | 0.2 | 0.1 | −0.2| 0.3 | 0.2 | 0.1 | −0.4|

| Treatment                  | Factor Score (Treatment-Wise) |
|----------------------------|--------------------------------|
|                            | F1  | F2  | F3  | F4  |
| B₁HA₃₀NPK₉₀                 | −2.0| 1.7 | −0.5| 0.7 |
| B₂HA₃₀NPK₉₀                 | −0.9| −1.0| −0.9| −0.3|
| B₁HA₆₀NPK₉₀                 | 2.7 | −2.0| −0.5| 0.2 |
| B₂HA₆₀NPK₉₀                 | 0.1 | 1.0 | −0.1| −0.2|
| B₁HA₃₀NPK₈₀                 | 2.7 | 0.2 | 0.5 | −1.2|
| B₂HA₃₀NPK₈₀                 | −0.8| 1.0 | −0.9| −0.2|
| B₁HA₆₀NPK₈₀                 | 4.9 | 0.5 | 1.3 | 0.4 |
| B₂HA₆₀NPK₈₀                 | 1.9 | −0.8| 0.1 | 0.7 |
| N:P:K (360:740:200)         | −8.6| −0.8| 1.0 | 0.1 |

YE, Yield efficiency; TCSA, trunk cross-sectional area; TCV, Tree canopy volume; PC1, Principal component-1; PC2, Principal component-2; PC3, Principal component-3; PC4, Principal component-4.

4. Conclusions

Foliar application of humic acid at 60 mL/L at bud burst stage along with soil application of bio-inoculants (PSB at 10 mL/plant + A. chroococcum at 10 g/plant) in rhizosphere zone along with 80 percent of RDF of NPK had positive and significant effects on morphometric, generative traits, flowering and fruiting behavior. Fruit qualitative traits were also improved during the winter season. The bio-organics application also improved chemical properties of soils. The reduction of 20 percent inorganic NPK fertilizers through inoculation of A. chroococcum, P-solubilizers and AM fungi was achieved, which might be responsible for better cropping behavior and productivity of guava under the meadow plant–soil interface in the winter season.
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References

1. Trevisan, S.; Francioso, O.; Quaggiotti, S.; Nardi, S. Humic substances biological activity at the plant soil interface from environmental aspects to molecular factors. Plant Signal. Behav. 2010, 5, 635–643. [CrossRef] [PubMed]

2. Bhat, T.A.; Gupta, M.; Ganai, M.A.; Ahanger, R.A.; Bhat, H.A. Yield, soil health and nutrient utilization of field pea (Pisum sativum L.) as affected by phosphorus and biofertilizers under subtropical conditions of Jammu. Int. J. Mol. Plant Sci. 2013, 1, 1–8.

3. Aya, H.; Gulser, F. The effects of sulfur and humic acid on yield components and macronutrient contents of spinach (Spinacia Oleracea var. Spinooza). J. Bio. Sci. 2005, 10, 801–804.

4. Navya, M.V.; Deepthi, C.; Mubeena, P.; Usha, C.T. Humic Substances: An Elixir to Plant Growth. Biotica Res. Today 2021, 3, 435–436.

5. Khalid, S.; Qureshi, K.M.; Hafiz, I.A.; Khan, K.S.; Qureshi, U.S. Effect of organic amendments on vegetative growth, fruit and yield quality of strawberry. Pak. J. Agric. Res. 2013, 26, 104–112.

6. Abd El-Razek, E.; Haggag, L.F.; El-Hady, A.; Shahin, E.S.M.F.M. Effect of soil application of humic acid and bio-humic on yield and fruit quality of “Kalamata” olive trees. Bull. Natl. Res. Cent. 2020, 44, 1–8. [CrossRef]

7. Zamani, A.; Karimi, M.; Abbasi-Surki, A.; Direkv-Moghadam, F. The effect of humic acid application on stevia (Stevia rebaudiana) growth and metabolites under drought stress. Iran. J. Plant Physiol. 2021, 11, 3651–3658.

8. El-Sayed, S.Y.S.; Hagab, R.H. Effect of organic acids and plant growth promoting rhizobacteria (PGPR) on biochemical content and productivity of wheat under saline soil conditions. Middle East J. Agric. Res. 2020, 9, 227–242.

9. Jan, J.A.; Nabi, G.; Khan, M.; Ahmad, S.; Shah, P.S.; Hussain, S. Foliar application of humic acid improves growth and yield of chilli (Capsicum annum L.) varieties. Pak. J. Agric. Res. 2020, 33, 461–472. [CrossRef]

10. El-Hoseiny, H.M.; Helaly, M.N.; Elsheery, N.I.; Alam-Eldein, S.M. Humic acid and boron to minimize the incidence of alternate bearing and improve the productivity and fruit quality of mango trees. Hort. Sci. 2020, 55, 1026–1037. [CrossRef]

11. Das, K.; Sau, S.; Datta, P.; Sengupta, D. Influence of biofertilizer on guava (Psidium guajava L.) cultivation in gangetic alluvial plain of West Bengal, India. J. Exp. Bio. Agric. Sci. 2017, 5, 476–482. [CrossRef]

12. Singh, Y.; Prakash, S.; Prakash, O.; Kumar, D. Effect of organic and inorganic sources of nutrients on available soil in Amrapali mango (Mangiferaindica L.) under high density planting. Int. J. Pure Appl. Biosci. 2017, 5, 93–98. [CrossRef]

13. Ibraheim, H.I.M.; Saied, H.H.M.; Awad, M.S.E.H. Effect of using humic acid and amino acids enriched with different nutrients as partial replacement of mineral nitrogen fertilizers in Zebda mango orchards. N. Y. Sci. J. 2018, 11, 62–71.

14. Nardi, S.; Pizzeghello, D.; Muscolo, A.; Vianello, A. Physiological effects of humic substances on higher plants. Soil Bio. Biochem. 2000, 34, 1527–1536. [CrossRef]

15. Satisha, G.; Devarajan, L. Humic substances and their complexation with phosphorus and calcium during composting of press mud and other biodegradables. Commun. Soil Sci. Plant Anal. 2005, 36, 805–818. [CrossRef]

16. Kumar, P.; Sharma, N.; Sharma, S.; Gupta, R. Rhizosphere stoichiometry, fruit yield, quality attributes and growth response to PGPR transplant amendments in strawberry (Fragaria × ananassa Duch.) growing on solarized soils. Sci. Hortic. 2020, 265, 108–121. [CrossRef]

17. Kumar, P.; Sharma, S.K.; Chandel, R.S.; Singh, J.; Kumar, A. Nutrient dynamics in pistachios (Pistacia vera L.): The effect of mode of nutrient supply on agronomic performance and alternate-bearing in dry temperate ecosystem. Sci. Hortic. 2016, 210, 108–121. [CrossRef]

18. Kumar, P.; Sharma, S.K.; Kumar, A. Foliar nutrient feeding affects generative potential of apples: Multilocation DOP indexing and PCA studies under dry temperate agro-climatic conditions of north-west Himalaya. Sci. Hortic. 2017, 218, 265–274. [CrossRef]

19. Kumar, P.; Chandel, R.S. Generative developments and pomological traits of apple (Malus × domestica Borkh.) scion cultivars canopy on dwarf clonal rootstocks in dry temperate ecosystem of north-west Himalayas. Sci. Hortic. 2017, 215, 28–37. [CrossRef]