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CORRELATION ANALYSIS OF HORTICULTURAL TRAITS OF APRICOT AS INFLUENCED BY PHYTO BIO-STIMULANTS

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ABSTRACT

To feed the growing population, phyto bio-stimulants play a key role in enhancing fruit yield without compromising quality, especially in the temperate fruit industry. Sitofex (CPPU) and Elanta Super (NATCA) are two new-generation phyto bio-stimulants in the fruit industry. To evaluate its efficacy on apricot, as many as 11 treatments with three replications comprising two doses of CPPU(5 and 10 ppm) and NATCA (50 and 100 ppm) and a combination of their lower doses (5 + 50 ppm) at two different stages *i.e.* pink bud stage (PBS) and petal fall stage (PFS) were designed. Results inferred that 10 ppm CPPU at PFS increased the overall vegetative growth, yield, and yield-attributing factors. On the other hand, 50 ppm NATCA at PBS reduced increased quality attributes of apricot fruits as compared to untreated control. A very strong relationship (R^2> 0.80) was observed among yield and annual shoot growth, leaf area, fruit set, fruit retention and fruit equatorial diameter. The regression analysis was also carried out between yield and yield attributing parameters to know the trend towards yield when phyto bio-stimulants were used.

Key words : Apricot, CPPU, NATCA, Petal fall stage, Pink bud stage, Phyto bio-stimulants.

Introduction

After the introduction of apricot (*Prunus armeniaca* L.) to India from its origin in North-Eastern China during the 19th century, it acclimatized to the Indian climatic conditions (Hota *et al.*, 2017a) and is being grown extensively in northern state of India including Himachal Pradesh, J&K, Uttarakhand and part of Arunachal Pradesh at an elevation of 900 m to 2000 m above MSLhaving 16145 MT annual production from 5690 ha areaduring 2020 (FAO, 2022). The nutritional potential of this particular crop makes it remarkable from other fruits. Although, it ranks 3rd among the stone fruits in production after peach and plum, its delicacy attracts consumers for its table as well as processed product consumption.

The genotype used in this experiment was "New Castle", which is very popular among the farmers of mid-hills of Himachal Pradesh, because of its low-moderate chilling hour requirement, attractive barium yellow colour, high qualitative index concerning juice content and sweetness (Hota *et al.*, 2017b). Apart from high horticultural importance, this particular genotype reaches to market during 3rd week of May (Hota *et al.*, 2017a), when no other variety is available showing its earliness in crop phenology and hence fetches a good remuneration to the growers.

The growing demand for this fruit is a lagging supply of quality fruit for table purposes. The crop being highly perishable, need careful attention from the farm to feed. It's still a grievance for the researcher to extend the shelf life of the fresh fruit without deteriorating its quality attributes. In past few decades, various cultural practices being adopted across the globe to maintain its quality, out of which application of phyto bio-stimulants seeks a special demand among the growers (De Pascale *et al.*, 2017), as a limited application in the field not only help the farmers in increasing yield but also helps in maintaining the quality parameters.

Out of various plant growth regulating chemicals, forchlorfenuron (CPPU or N-[2-chloro-1-pyridinyl]-N phenylurea) stands to be a new generation growth regulator having cytokinin properties (Hota *et al.*, 2020). Inherit properties of cytokinin make this chemical widely adaptive to the fruit industry in various crops like grape, kiwi, apple, cherry and apricot. Concerning the mode of action, this chemical increases the canopy volume and leaf area by enhancing chlorophyll formation, increasing fruit set and fruit retention, and thereby increases fruit yield (Khot *et al.*, 2015). The other yield-attributing characters include an increase in fruit size and fruit weight, which are also induced by CPPU by increasing the number of cells. Not only the quantitative aspect of fruit production but also qualitative parameters (fruit firmness, TSS, colour) are being up-surged by CPPU (Wang *et al.*, 2017). It extends the shelf life of fruit either by delaying the cell division or by suppressing the gene responsible for the up-regulation of polygalacturonase or cellulose (Hota *et al.*, 2020). CPPU dissipates in the fruits (Chen *et al.*, 2013) and as well as in soil (Banerjee *et al.*, 2008) in a very fast way, showing its environment-friendly properties.

Similarly, NATCA is a new organic bio-stimulant having the chemical name N-acetyl thiazolidine 4-carboxylic acid and the generic name of Elanta Super and Homan; is gaining popularity in the fruit industryafter being introduced by Coromandel Fertilizers, Secunderabad, India. Being an organic amino acid derivative, it significantly showed its positive response on fruit set, fruit retention, physical attributes of fruits, and the qualitative aspect of fruit (Hota *et al.*, 2018). Not only the physicochemical properties of fruits being affected by this plant bio-regulator, but it also helps as a buffering agent during stress conditions to mitigate heat stress (Hota *et al.*, 2019). To check out the efficacy of these bio-regulators individually or in combination, this experiment was carried out to evaluate the performance of these bio-regulators on the growth, yield and quality of apricot.

Materials and Methods

Experimental location

The experiment was laid at the fruit orchard of Dr.YSPUHF, Solan, Himachal Pradesh, India during the years 2014-15 and 2015-16. The geographic location of the experimental fruit orchard lies in the mid-hills of Himachal Pradesh (India) at 30.51^{o} N latitude and 76.11^{o} E longitude at 1250 meter above MSL. The geographic area falls under sub-temperate and semi-humid climatic zone experiencing via way of means of slight summers and chilling winters. During the cropping season, the mean temperature varied from 9.85 to 32.50°C while relative humidity ranged from 45 to 63 per cent. The annual rainfall ranges between 110-120 cm and the major amount of which is received during June to September.

Plant materials

To carry out this experiment, 8-year-old 33 uniform vigour plants of "New Castle" were selected. The experimental trees had been planted at a spacing of 3m × 3m in square planting system, which were grafted on wild apricot (Chuli) root stock and trained to modified leader system.

Experimental details

As many as 11 different treatments (T_1- CPPU 5 ppm at PBS; T_2- CPPU 10 ppm at PBS; T_3- CPPU 5 ppm at PFS; T_4- CPPU 10 ppm at PFS; T_5- NATCA 50 ppm at PBS; T_6- NATCA 100 ppm at PBS; T_7- NATCA 50 ppm at PFS; T_8- NATCA 100 ppm at PFS; T_9- CPPU 5 ppm + NATCA 50 ppm at PBS; T_{10}- CPPU 5 ppm + NATCA 50 ppm at PFS and T_{11}- Control) carrying various concentrations of CPPU (5 and 10 ppm) and NATCA (50 and 100 ppm), and combination of their lower doses (5 + 50 ppm) at two different stages *i.e.* pink bud stage (PBS) and petal fall stage (PFS) were designed for the experimental trees. The experiment was replicated thrice in randomized block design. The desired strength of spray solutions of CPPU (Sitofex- 0.92% active ingredient) and NATCA (Elanta Super-10% active ingredient) wasestimated and made by dissolving directly the required volume of their commercial formulations in water. A spray solution of 10 litres was made for each treatment where, a few drops of Teepol (surfactant) were added to reduce the surface tension of water droplet and maximum absorption by the plant cell.

Spraying methodology

The treatments involving different phyto bio-stimulants were sprayed on the plant canopy without causing runoff using a foot sprayer (ASPEE Maruti Foot Sprayer MRI8) during PBS and PFS. The PBS was achieved during the 2^{nd} week of February and the PFS was observed 15 days after the PBS. To avoid dilution of any particular strength of spray solution utilized, the spray was initiated with lower concentrations of each ingredient. The sprayer was washed with a tiny amount of solution before resuming the spray with the next higher concentration. Only water was sprayed in the control group. To achieve the best results, the spraying operation was carried out during the morning hours on a clear and calm day.

Observation recorded

To record the annual shoot growth, 10 current season growth shoots from each direction of the canopy were selected and measured. Trunk girth was measured 30 cm above the ground level. The canopy volume of the tree was the result of plant height, and plant spread (east-west and north-south), calculated using the formula $4/3\pi ab^2$, where a was 1/2 the length of the major axis (height) and b was 1/2 the length of the minor axis (spread), as per the formula given by Westwood (1978). During the last week of June, 25 matured leaves were randomly selected from previously tagged branches located around the tree canopy and leaf area was measured with the help of Portable Laser Leaf Area Meter (Model No: CI-202). The chlorophyll content of the leaves was measured by the portable Chlorophyll Fluorometer (Opti-Sciences < OS-30p>; made in U.S.A.). To evaluate the fruiting potential randomly four fruiting branches from all four directions of the plant canopy were chosen and tagged for observation. Fruit set, fruit retention, and fruit drop were evaluated as per the formula proposed by Westwood (1978).

Statistical analysis

Statistical analysis was performed using MS-Excel and OPSTAT for each observed character in the study. By using Randomized Block Design (RBD), the data collected from these experiments were suitably computed, tabulated, and evaluated. At a 5% level of significance, the level of significance for several variables was examined.

Results and Discussion

Response on vegetative growth

The data in response to various phyto bio-stimulants treatments showed a significant difference during experimentation (Fig. 1). Plants treated with 10 ppm CPPU at PFS (T_4) exerted significant increase in the vegetative parameters including annual shoot growth, percent increase in canopy volume and leaf area. However, treatment T_4 (CPPU 10 ppm at PFS) was observed statistically on par with treatments T_3 (CPPU 5 ppm at PFS) and T_{10} (CPPU 5 ppm + NATCA 50 ppm at PFS). The maximum chlorophyll content was recorded with the treatment T_8 (100 ppm NATCA at PFS), statistically on par with the treatment T_7(50 ppm NATCA at PFS), but significantly higher than the remaining treatments. The minimum increase in vegetative growth (annual shoot growth, percent increase in canopy volume, leaf area and chlorophyll content) was observed with control (T_1), where no bio-stimulant was applied. Amongst the two phyto bio-stimulant, CPPU performed excellent compared to NATCA in view of overall vegetative growth performance. It was evident from the figure that application of any phyto bio-stimulant showed a superior response at PFS compared to PBS.

Cytokinin has an inhibitory influence on IAA oxidase production and initiates a sink mechanism at lateral bud sites by which vascular differentiation starts and translocation of water & nutrients including other growth-promoting substances like vitamins & minerals, occurs (Hota *et al*., 2020), as a consequence, lateral bud emerges. Acquiring the cytokinin activity, CPPU may hold back the apical dominance and upsurge thereby causing axillary shoot development. Additional intention for the encouragement of growth may be connected to arise in RNA and DNA volume, polymerase action and protein production (Hota *et al*., 2018). In present study, CPPU at PFS increased the vegetative parameters of apricot, which were in lined with Thakur *et al*. (2019a; 2019b), who observed an increased annual shoot growth, trunk girth, canopy volume, net photosynthetic rate, stomatal conductance, and transpiration rate by applying 10 ppm CPPU at PFS. In the present study NATCA enhanced the chlorophyll content of the leaves, following the results of Hota *et al*. (2019), who reported an increase in chlorophyll content in the samples with the application of Agrispon and Ergostim (NATCA), which were similar active ingredients and products that of Elanta Super. Similar findings were also observed by Ramteke and Khot (2015), who reported that increased chlorophyll content of grapevine leaves was obtained from plants treated with 1 ml Elanta Super along with 15 ppm GA_3 + 1 ppm CPPU.

Response on fruiting potential

The data presented in Fig. 2 showed a varying

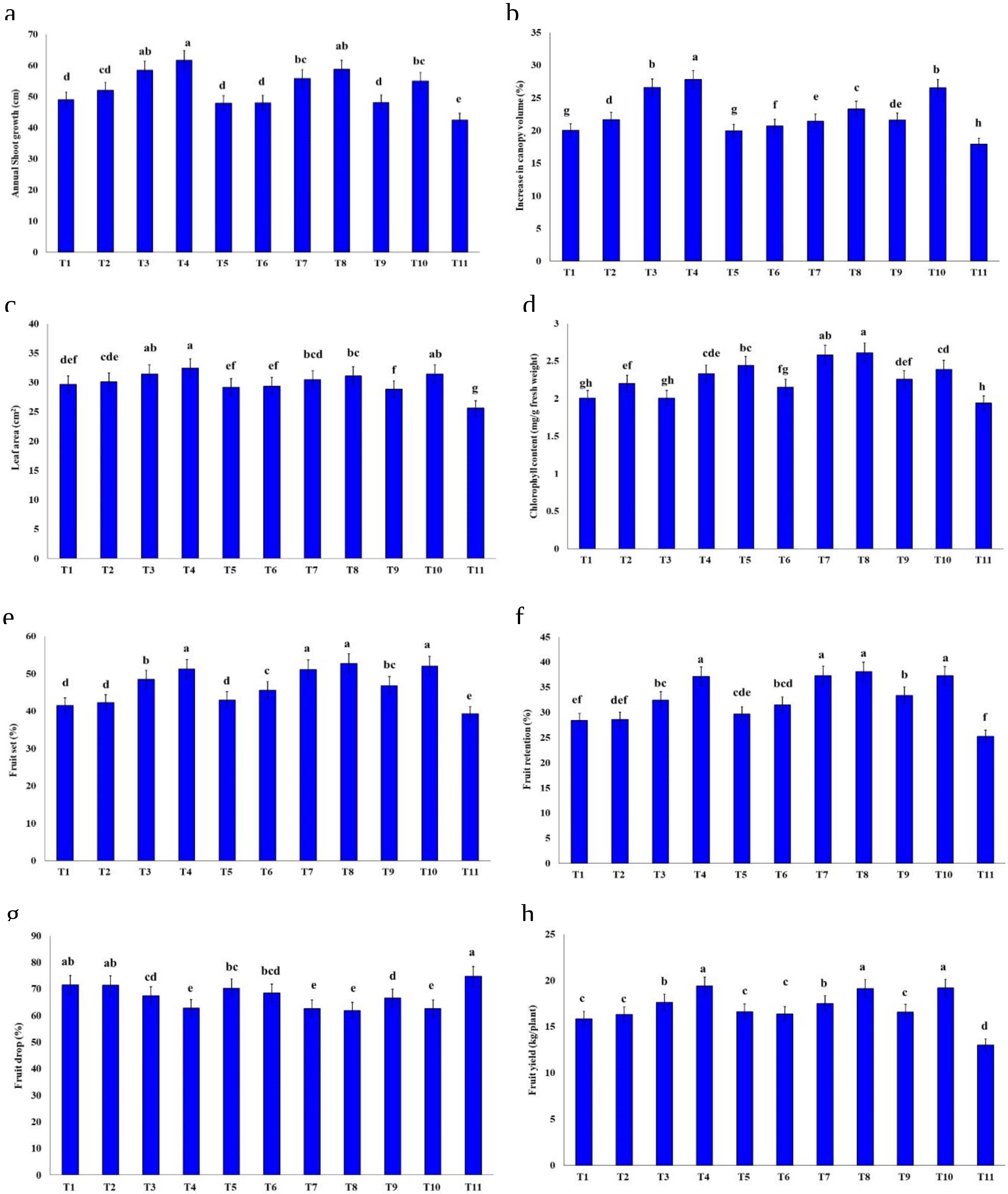

Fig. 1 : Response of phyto bio-stimulants on vegetative growth [a. annual shoot growth (cm), b. Percent increase in canopy volume (%), c. leaf area (cm^2) and d. chlorophyll content (mg g^{-1} fresh weight of leaves)] and fruiting potential [e. fruit set (%), f. fruit retention (%), g. fruit drop (cm^2) and h. fruit yield (kg $plant^{-1}$)] of apricot cv. New Castle (Pooled: 2014-16). T_1- CPPU 5 ppm at PBS; T_2- CPPU 10 ppm at PBS; T_3- CPPU 5 ppm at PFS; T_4- CPPU 10 ppm at PFS; T_5- NATCA 50 ppm at PBS; T_6- NATCA 100 ppm at PBS; T_7- NATCA 50 ppm at PFS; T_8- NATCA 100 ppm at PFS; T_9- CPPU 5 ppm + NATCA 50 ppm at PBS; T_{10}- CPPU 5 ppm + NATCA 50 ppm at PFS and T_{11}- Control.

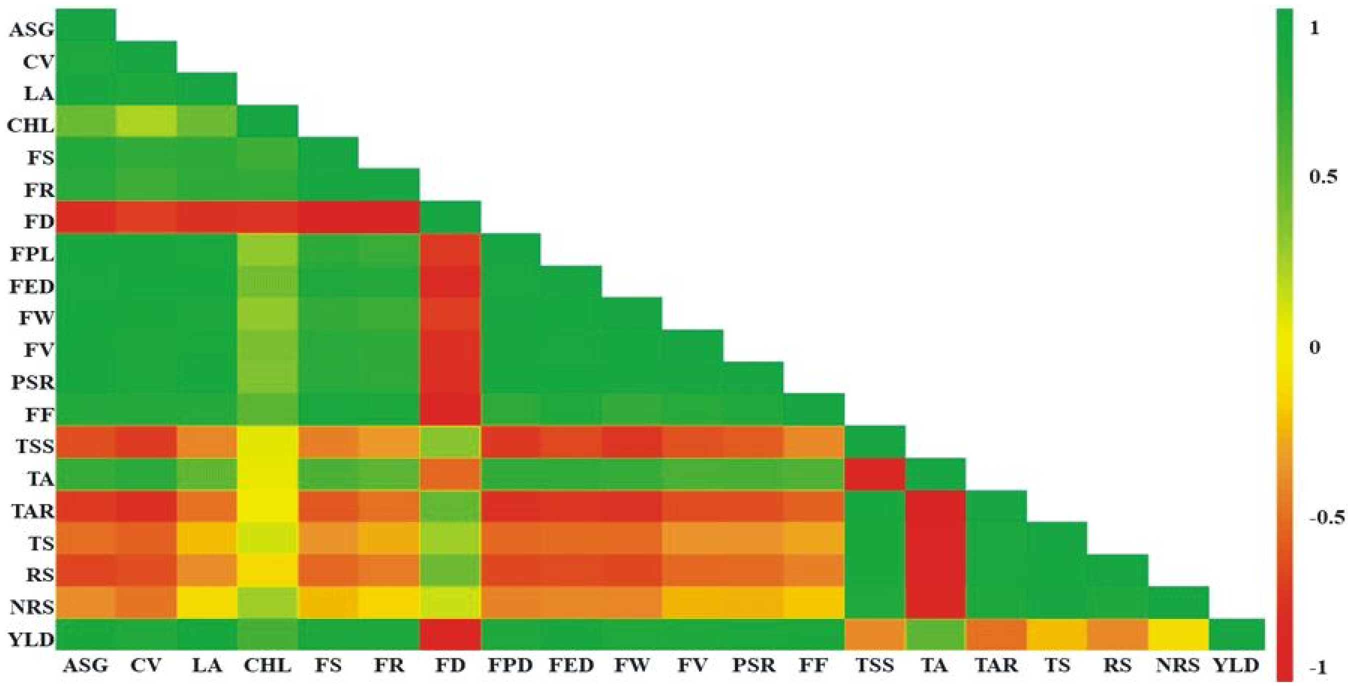

Fig. 2 : Correlation heat map between fruit yield and different *horticultural parameters of apricot irrespective of phyto-biostimulants application.* ASG- Annual shoot growth; CV- Canopy volume; LA- Leaf area; CHL- Chlorophyll content; FS- Fruit set; FR- Fruit retention; FD- Fruit drop; FPD- Fruit polar diameter; FED- Fruit equatorial diameter; FW- Fruit weight; FV- Fruit volume; PSR- Pulp: stone ratio; FF- Fruit firmness; TSS- Total soluble solids; TA- Titratable acidity; TAR- TSS: acid ratio; TS- Total sugars; RS- Reducing sugars, NRS- Non-reducing sugars; YLD- Fruit yield.

magnitude of the response on fruiting potential percentage as affected by different phyto bio-stimulant treatments in apricot. Both the phyto bio-stimulants significantly influenced fruit set, fruit retention, fruit drop and yield. The maximum fruit set and fruit retention were observed with treatment T_8 (NATCA 100 ppm at PFS), statistically on par with treatments T_4 (CPPU 10 ppmat PFS), T_7 (NATCA 50 ppm at PFS) and T_{10} (CPPU 5 ppm + NATCA 50 ppm at PFS), showing the significance of application time of phyto bio-regulators in improving the fruiting potential. On the other hand, treatment T_8 (NATCA 100 ppm at PFS) significantly reduced the fruit drop percentage. The treatment T_8 was statistically on par with treatments like T_4 (CPPU 10 ppmat PFS), T7 (NATCA 50 ppm at PFS) and T_{10} (CPPU 5 ppm + NATCA 50 ppm at PFS), showing the importance of phyto bio-stimulants in reducing the total fruit drop which include all the fruit drop waves, which ultimately resulted in increasing total fruit yield. A similar trend was also followed in the fruit yield parameter, where maximum fruit yield was observed with plants receiving 10 ppm CPPU at PFS (T_4), statistically on par with treatments such as T_8 (NATCA 100 ppm at PFS) and T_{10} (CPPU 5 ppm + NATCA 50 ppm at PFS), suggesting the role of phyto bio-stimulants in increasing the yield potential. An increase in fruit set, fruit retention and minimizing the fruit drops led to an increase in fruit yield. On contrary, minimum fruit set, fruit retention, fruit yield and maximum fruit drop was observed with plants treated with no phyto bio-stimulants (T_1).

PFS is considered to be the fruit bud differentiation stage, where just after fertilization fruit starts to develop. The requirements of growth stimulants are quite high to divide and multiply the growing cells as it coincides with the lag phase of stone fruit development. External application of amino acids, increase the levels of proline and hydroxyproline (an organic substance used against abiotic stress tolerance), promote mineral chelation and transportation, provoking enzymes (such as peptidase, phosphorylase, nitrate reductase, phosphatase, and malate dehydrogenase) leading to enhancedchlorophyll production along with increased flower and fruit set (Hota *et al.*, 2020). As a result, the use of amino acid bio-stimulants has been linked to increased biomass build-up and/or fruit yield in many fruit crops (Maini, 2006). In the present investigation, treatment containing 10 ppm CPPU and 100 ppm NATCA at PFS was observed to have higher fruit yield. Accumulation of higher rates of auxin and cytokinin after the pollination and fertilization accelerates increased fruit set and size of the fruit. The rising of endogenous hormone in the ovule just after the petal fall stage decreased fruitlet drop of pear (Silva *et al.*, 2010). Application of CPPU increases the hydroxycinnamic

Table 1: Regression equation fitting between yield and yield attributing parameters irrespective of phyto bio-stimulants application.

S. no.	Regression equation	R^2 value		S. no.	Regression equation	R^2 value
1	Yield = 14.575 ln(annual shoot growth) - 40.593	0.80		11	Yield= $6.304e^{0.0745 \text{fruit volume}}$	0.78
2	Yield = $8.75e^{0.0294 \text{canopy volume}}$	0.68		12	Yield = $2.7871e^{0.9263 \text{pulp to stone ratio}}$	0.78
3	Yield = 0.0186 (leaf area)^2 - 0.1338 (leaf area) + 4.3181	0.87		13	Yield = 5.255 fruit firmness + 2.8711	0.80
4	Yield = $8.0266e^{0.3301 \text{chlorophyll content}}$	0.44		14	Yield = 2.6832 TSS^2- 77.916 TSS + 581.88	0.26
5	Yield = 0.3791 fruit set$^{0.9898}$	0.82		15	Yield = 19.967 titratable acidity + 0.0053	0.28
6	Yield = $7.9906e^{0.023 \text{fruit retention}}$	0.80		16	Yield = 0.2373 (TSS: acid ratio)^2 - 8.499 (TSS: acid ratio)+ 92.339	0.31
7	Yield = 11252 fruit drop$^{-1.544}$	0.79		17	Yield = -1.6425 (total sugar)^2 + 27.43 (total sugar) - 96.763	0.09
8	Yield = 0.0276 fruit polar diameter$^{1.9316}$	0.73		18	Yield = 10.508 (reducing sugar)^2 - 68.109 (reducing sugar) + 126.62	0.20
9	Yield = 32.996 ln(fruit equatorial diameter) - 93.083	0.86		19	Yield = -7.2633 (non-reducing sugar)^2 + 75.05 (non-reducing sugar) - 175.77	0.13
10	Yield = $6.9054e^{0.0634 \text{fruit weight}}$	0.69				

amides (an organic compound that helps in flower induction and fruit set) content through conjugated polyamines resulting in increasing fruit set and fruit yield (Shiozaki *et al*., 2014).

Correlation and regression analysis

The correlation matrix presented through Fig. 2 suggested that fruit yield was strongly related to different horticultural parameters to varying properties. The correlation matrix showed that fruit yield was positively correlated with annual shoot growth (r = 0.89, p = 0.01), canopy volume (r = 0.84, p = 0.01), leaf area (r = 0.94, p = 0.01), fruit set (r = 0.91, p = 0.01), fruit retention (r = 0.90, p = 0.01), fruit polar diameter (r = 0.87, p = 0.01), fruit equatorial diameter (r = 0.92, p = 0.01), fruit weight (r = 0.85, p = 0.01), fruit volume (r = 0.86, p = 0.01) and fruit firmness (r = 0.89, p = 0.01). However, a strong negative correlation was observed with yield and fruit drop (r = -0.90, p = 0.01), TSS (r = -0.41, p = 0.05), TSS: acid ratio (r = -0.50, p = 0.05). The regression analysis was also carried out between yield and yield attributing parameters to know the trend towards yield when phyto-bio stimulants were used (Table 1). Annual shoot growth and fruit equatorial diameter were the best fit in the logarithmic curve about increasing yield. While, canopy volume, chlorophyll content, fruit retention, fruit weight, fruit volume and pulp: stone ratio were best fit in exponential growth curve. The polynomial curve was fitted in leaf area, TSS, TSS: acid ratio, total sugars, reducing sugars and non-reducing sugars with increasing yield. Fruit set and fruit drop were best fit in power growth curve. To evaluate the correlation between variables, it is important to know the "magnitude" or "strength" as well as the significance of the correlation. The coefficient of determination (R^2) expresses the amount of common variation between the two variables. A very strong relationship (R^2> 0.80) was observed among yield and annual shoot growth (R^2 = 0.80), leaf area (R^2 = 0.87), fruit set (R^2= 0.82), fruit retention (R^2 = 0.80) and fruit equatorial diameter (R^2 = 0.86), suggesting the importance of phyto bio-stimulants in correlating between yield and yield attributing parameters. Similar results were observed by Mratiniæ *et al*. (2007) in apricot, who reported a positive correlation between fruit physical parameters and yield.

Conclusion

Phyto bio-stimulants are excellent molecules to fulfil the growing demand of the apricot industry. They are specific in their function concerning concentration and time of application and are hardly used pleiotropically. In this experiment, it was observed that 5 ppm CPPU at PFS revealed a superior response for vegetative growth, yield, and physical horticultural traits of apricot fruit. While 50 ppm NATCA at the pink bud stage showed a significant increase in chlorophyll content and qualitative traits fruit. Hence, these phyto bio-stimulants can be utilized as farmer-friendly bio-stimulants to enhance the apricot fruit industry in mid-hills; however, its application can also be explored in other crops to evaluate its efficiency.

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