



GROWTH, PHYSIOLOGICAL RESPONSE AND YIELD PERFORMANCE OF TOMATO UNDER FOLIAR APPLICATION OF A FLAVONOID BASED SOLUTION

Ganesh N. Jadhav¹, Riddhi S. Rane², Ravikumar³, Dinkar Phad³

¹Senior Scientist, Aussan Laboratories India

²Research and Development Executive, Aussan Laboratories India

³Agronomist, Aussan Laboratories India

Corresponding author email: ganeshanjadhav@gmail.com

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ABSTRACT:

A field experiment was conducted in Rabi 2023-24 at the Regional Agricultural Research Station, Acharya N.G. Ranga Agricultural University, Guntur, Andhra Pradesh, India, to evaluate the bio efficacy of an eco-friendly flavonoid-based foliar spray, CropBioLife (CBL) on growth and physiological parameters yield and quality of tomato (*Solanum lycopersicum* L.). The experiment was laid out in a randomized block design consisting of eight treatments and replicated thrice. The treatments included CBL at four concentrations (0.5, 1.0, 2.0 and 4.0 mL L⁻¹), triacontanol, salicylic acid, azoxystrobin and a control (no treatment). All treatments were applied by foliar method at (5, 30 and 60 DAS). The results indicated that the CBL at 4.0 mL L⁻¹ increased the number of branches per plant, number of flowers per plant, number of fruits per plant, percentage fruit set, chlorophyll content (SPAD), photosynthetic rate and CBL at 4.0 mL L⁻¹ gave the highest yields (1.49 kg plant⁻¹). CBL at the 4.0 mL L⁻¹ treatment also provided the greatest contribution to increased soil organic carbon and therefore may be beneficial for soil health. Although disease incidence (wilt and fruit borer) was also noted on all treatments (including the control), CBL treatments retained the most physiological vigor and fruit quality. The above results suggest that CBL can be integrated into sustainable tomato production systems to increase productivity and quality, promote soil health and to be utilized with other pest and disease management interventions.

Keywords tomato, CropBioLife, bioflavonoid, yield, photosynthesis, soil health.

INTRODUCTION:

Tomato (*Solanum lycopersicum* L.) as a dominant horticultural crop, is loved for fresh consumption and processing, but effective production suffers from inadequate nutrition and transient abiotic stresses that impact growth, fruit set and quality. Growers are increasingly looking for possible opportunities to improve nutrition aspects of their production in tomatoes while also improving aspects of stress tolerance through the application of flavonoid-based foliar sprays, which are described as non-nutrients but beneficial substances of plant or biological origin that activate natural plant systems to improve nutrient usage efficiency while positively impacting stress

durability and crop quality while reducing reliance on synthetic inputs (du Jardin, 2015).

Of all the plant-based possible categories described to date, extracts and protein hydrolysates are particularly interesting in that they improve physiological performance in tomatoes (through improvement in chlorophyll content and activity of active photosynthesis), antioxidant capacity, and yield components under heat stress or mild and transient restriction of water (Francesca *et al.*, 2020). On-farm and greenhouse field research undertaken in Canada through IDRC programs also highlight the skills of enhancing outreach and extension formulations and delivery mechanisms; demonstrating that

when used with conventional fertility and crop protection practices, in-farm applications with traditional practices can increase marketable yield (Shahid & Liu, 2022).

Flavonoid based foliar sprays contain plant derived compounds that can influence physiological processes. They may support chlorophyll formation and photosynthetic activity as reported in earlier work where flavonoids acted as antioxidants in plant tissues (Agati *et al.*, 2012). Other studies have shown that natural extracts and similar plant based formulations improve leaf greenness, gas exchange and yield related traits in tomato under mild stress conditions (Francesca *et al.*, 2020). These responses are linked to improved metabolic activity and better tolerance to environmental fluctuations.

Despite this potential, information on flavonoid enriched solutions under Indian field conditions is limited. Many comparative studies focus on bio-stimulant categories in general, which include protein hydrolysates, extracts and related substances that influence nutrient use efficiency and plant performance (Calvo *et al.*, 2014). However, direct evaluations of flavonoid sprays against common inputs such as triacontanol, salicylic acid or Azoxystrobin remain scarce. The lack of field based evidence restricts understanding of their practical contribution to tomato cultivation.

The present study was carried out to address this gap. The objective was to evaluate the effect of a flavonoid enriched foliar spray on growth traits, physiological parameters and yield of tomato in open field conditions, and to compare its performance with selected standard treatments and an untreated control.

Accordingly, the current experiment assessed CropBioLife, a flavonoid-based foliar spray developed by Aussan Laboratories Australia, with standard Azoxystrobin schedules and a few

commercial bio agents available to farmers worldwide. This trial occurred in open-field tomato during Rabi 2023-24 at the Regional Agricultural Research Station of ANGRAU, Guntur (Andhra Pradesh, India). The working hypothesis was that a foliar application of the extracts at early growth and flowering stages would improve growth and vegetative and flowering health, subsequently leading to more yield and selected quality characteristics and could either perform comparably or in synergy with Azoxystrobin based schedules (du Jardin, 2015; Francesca *et al.*, 2020; Shahid & Liu, 2022).

MATERIALS AND METHODS

2.1 Experimental site and plant material

The field trial was conducted during Rabi 2023-24 at the Regional Agricultural Research Station, Acharya N. G. Ranga Agricultural University (ANGRAU), Guntur, Andhra Pradesh, India. Tomato hybrid 'Saaho' was selected for the experiment. Seedlings were procured from a nursery in Chinnagottigallu village of Tirupati and transplanted at 25 days of age on 2 February 2024. Routine agronomy (land preparation, irrigation, staking/pruning as required and plant protection unrelated to test treatments) followed local recommendations. The recommended dose of fertilizers was applied as the basal program; test inputs were superimposed as foliar sprays as described below.

2.2 Cultural Practices

Tomato seedlings were planted on broad beds with a width of 1 metre. Each plot measured 12 metres by 2.5 metres and the crop was spaced at 60*45 centimetres. Irrigation was provided as per requirement using a drip system. Pendimethalin at 5 mL/L was applied as a pre emergence herbicide. Chrysanthemum seedlings were planted on border beds to act as a border crop. Fertilizers were applied at the recommended rate of 120 kilograms nitrogen, 80 kilograms phosphorus and 50 kilograms potassium per

hectare. Half of the nitrogen and the full dose of phosphorus and potassium were applied at planting. The remaining nitrogen was top dressed at 30 days after planting. Fertilizers were placed for each plant by pocketing at a distance of 5 to 7 centimetres from the stem and covered with soil. Carbendazim at 1.0 gram per litre and Mancozeb at 2.5 grams per litre were applied as a drench at 35 days after sowing. Manual weeding was carried out as necessary. Metribuzin at 1.5 grams per litre and liquid propaquizalofop at 1.5 millilitres per litre were sprayed at 40 days after sowing for weed management. Lufenuron was not used. Instead, Lufen diamide at 0.3 millilitres per litre was sprayed at 45 days after sowing against tomato fruit borer. Staking was completed at 35 days after planting to prevent lodging and support vertical growth.

Fruits reached physiological maturity at about 65 days after planting. Harvesting was done at intervals of three to four days depending on market demand. A total of eight pickings were taken and yields ranged from 1.3 to 1.85 tonnes per hectare. The final harvest was completed at 120 days after planting.

2.3 Experimental design and treatments

The experiment followed a randomized block design (RBD) with eight treatments (T₁-T₈) and three replications. Each plot consisted of uniform rows of tomato with standard spacing as per station practice; border rows were used to minimize spray drift.

Treatments (all applied as foliar sprays at 5, 30 and 60 days after transplanting, unless otherwise stated) were:

- T₁: Untreated control
- T₂: CBL @0.5 mL/L
- T₃: CBL @1.0 mL/L
- T₄: CBL @2.0 mL/L
- T₅: CBL @4.0 mL/L
- T₆: Triaconitol 1.0% EW @1.0 mL/L

- T₇: Salicylic acid (1M) @1.0 mL/L
- T₈: Azoxystrobin 23 % SL @0.5 mL/L

The Azoxystrobin rates represent standard field concentrations in Indian tomato programs and were selected to bracket common practice. CBL concentration was chosen in line with prior tomato flavonoid application studies showing positive physiological and quality responses to vegetal extracts under stress (Francesca *et al.*, 2020).

2.4 Spray Application

Foliar treatments were applied using a knapsack sprayer fitted with a cone nozzle at a spray volume of about 500 to 600 litres per hectare. Application was done under calm weather to ensure complete leaf coverage. The control plots received water at the same timings.

2.5 Method of Sampling and Data Collection

2.5.1 Physiological Parameters

Plant height, number of branches plant⁻¹ and SPAD chlorophyll index was measured during key phenophases (vegetative, flowering and early fruiting). SPAD was measured on uppermost fully expanded leaves (3-5 per plant; ten plants plot⁻¹), using a hand-held chlorophyll meter (SPAD-502/502Plus; Konica Minolta), a commonly-utilized non-destructive metric based on correlations with tomato leaf chlorophyll and N status (Jiang *et al.* 2017). Phosphorus was analysed using a UV spectrophotometer and potassium was measured using a flame photometer. Micronutrients were analysed using an atomic absorption spectrophotometer.

2.5.2 Yield and fruit quality

Marketable fruit number plant⁻¹, mean fruit weight (g) and yield (t ha⁻¹) were documented from the central harvest area of each plot across pickings and summed to create season totals. Quality fruit traits (total soluble solids, titratable acidity and ascorbic acid) were assessed on composite samples per plot, following standard

laboratory protocols in tomato quality evaluation (Francesca *et al.*, 2020).

2.5.3 Soil Parameters

Soil organic carbon was estimated at harvest by the Walkley and Black method (Walkley and Black, 1934).

2.5.4 Statistical analysis

Data were subjected to analysis of variance (ANOVA) for an RBD. When treatment effects were significant, means were separated at the 5% level. All analyses followed the procedures of Gomez and Gomez (1984).

1. Results

3.1 Phenological and Yield Attributes

The use of CropBioLife (CBL) had a distinct effect on many of the phenological parameters of tomato

except for height which did not show a significant difference between treatments. The means were greatest for branches per plant in T₅ (CBL @ 4.0 mL L⁻¹), and followed by T₆ (Triacontanol 1.0% EW) and T₄ (CBL @ 2.0 mL L⁻¹). For flower count and fruit number per plant and percentage fruit set were all at the highest levels in T₅.

Yield per plant differed significantly among treatments. The highest yield of 1.49 kilograms per plant was produced by T₅. Treatments T₄, T₆ and T₃ recorded intermediate yields while the control recorded the lowest value.

Table 1 provides the complete data on plant height, number of branches, flower count, fruit number, fruit set and yield.

Table 1: Effect of CBL on physiological and yield traits of tomato

Sr. No	Treatments	Plant height (cm) at harvest	No .of branches/pla nt at harvest	No. of flowers/pla nt	No. of fruits per plant	Fruit set per plant	yield / plant (Kg/ plant)
1	Control	103.8	8.53	27.50	15.43	56.11	1.0918
2	CBL @ 0.5 mL/L	111.6	8.33	34.17	17.21	50.37	1.0715
3	CBL @ 1 mL/L	113.5	8.75	35.00	17.75	50.71	1.1068
4	CBL @ 2 mL/L	111.6	9.33	39.58	19.24	48.61	1.2546
5	CBL @ 4 mL/L	115.8	11.92	43.33	25.63	59.15	1.4874
6	Triacontanol 0.1 % EW @1 mL/l	110.3	10.00	32.92	14.26	43.32	1.1354
7	Salicylic acid (1M) @ 1 mL/L	112.7	7.08	30.42	14.52	47.74	1.0847
8	Azoxystrobin 23 % SC	109.8	9.58	31.67	15.14	47.81	1.1288
	S.Em.	12.41	0.143	0.331	0.141	0.260	0.121
	CD (0.5%)	NS	0.434	1.003	0.427	0.780	0.367

3.2 Physiological Parameters

Chlorophyll content, as assessed by SPAD, was greatest in T₅ (53.77) while T₆ (52.07) was next indicating higher leaf greenness and based on the study by Jiang *et al.*,

(2017), nitrogen assimilation efficiency. The photosynthetic rate was the most responsive, especially with T₅ (13.20 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) and T₄ (11.32 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$) at 75 days after planting.

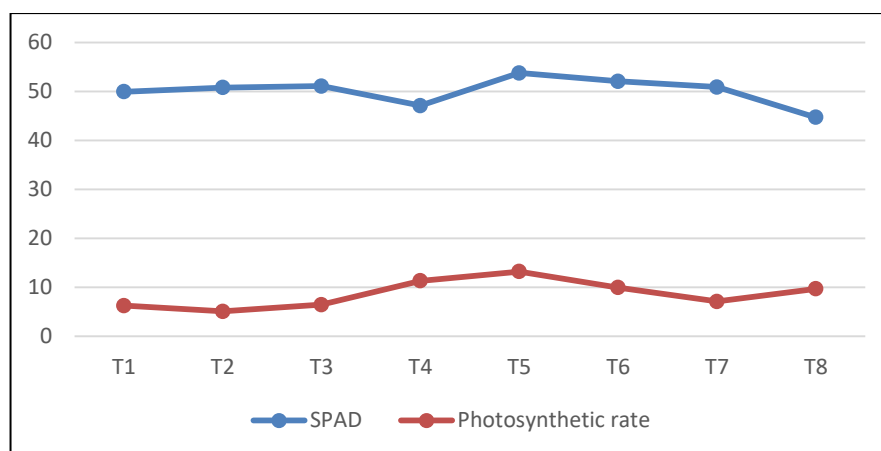


Fig. 1 Effect of CropBioLife and Other Treatments on Chlorophyll Content (SPAD) and Photosynthetic Rate in Tomato at 75 DAP

3.3 Yield Summary

A total of eight pickings were taken. Yields ranged from 1.09 to 1.49 kilograms per plant across treatments. The

highest yield was recorded in T₅ and the lowest in the untreated control. Figure 2 indicates the yield per plant across different treatments.

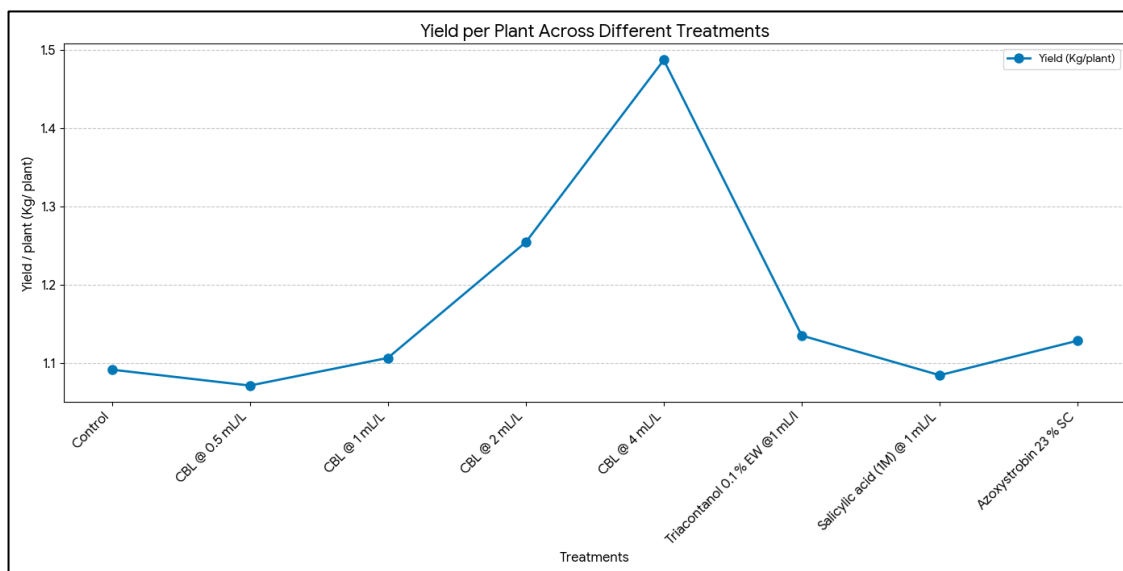


Fig. 2 Comparison of Average Yield per Plant (Kg/plant) among Control, CBL Concentrations and Other Chemical Treatments.

3.4 Nutrient and Micronutrient Status

Leaf nutrient and micronutrient concentrations recorded at 75 days after planting showed no statistically significant differences among treatments. Nitrogen content ranged from 0.257 to 0.373 percent. Potassium ranged from 0.420 to 0.490 percent and phosphorus values showed narrow variation among treatments.

Micronutrient levels of Fe, Mn, Zn and Cu showed numerical differences but all remained statistically non

significant. Iron content ranged from 24.20 to 33.15 milligrams per kilogram. Manganese ranged from 9.98 to 15.30 milligrams per kilogram. Zinc ranged from 4.65 to 7.27 milligrams per kilogram and copper ranged from 5.23 to 8.78 milligrams per kilogram.

Soil organic carbon at harvest ranged from 0.43 to 0.69 percent with the highest value recorded in T₅.

Table 2: Effect of CBL on organic carbon in the soil, macro and micronutrients composition of tomato

S. No	Treatments	N (%)	P (%)	K (%)	Fe (mg/Kg)	Mn (mg/Kg)	Zn (mg/Kg)	Cu (mg/Kg)	OC (%)
1	Control	0.257	0.048	0.423	30.06	13.22	5.25	5.57	0.60
2	CBL @ 0.5 ml/L	0.280	0.044	0.420	28.08	13.52	5.48	7.43	0.54
3	CBL @ 1 ml/L	0.327	0.043	0.450	24.20	9.98	6.06	6.71	0.43
4	CBL @ 2 ml/L	0.373	0.042	0.463	28.83	11.50	7.27	7.52	0.57
5	CBL @ 4 ml/L	0.350	0.047	0.457	32.63	14.18	5.12	8.78	0.69
6	Triacantanol 0.1 % EW @1 ml/l	0.327	0.045	0.490	33.15	15.30	4.65	6.11	0.57
7	Salicylic acid (1M) @ 1 ml/L	0.373	0.038	0.460	29.99	13.47	5.33	8.58	0.66
8	Azoxystrobin 23 % SC	0.280	0.039	0.423	29.15	13.04	6.42	5.23	0.61
	Mean	0.321	0.043	0.448	30.13	13.03	5.82	6.99	0.58
	S.Em.	0.032	0.005	0.039	4.23	1.79	0.774	1.59	0.055
	CD (0.5%)	NS	NS	NS	NS	NS	NS	NS	NS
	CV(%)	17.2	18.3	15.3	24.3	23.9	23.0	15.4	16.6

3.5 DISEASE INCIDENCE

At 35 DAP, wilt symptoms were scored across all treatments and fruit borer damage was first observed at 45 DAP. The CBL-treated plots had no observable increase in severity of disease when comparing the control, indicating that while CBL improved physiological performance, it did not replace pest or disease management.

2. DISCUSSION

The application of the flavonoid enriched foliar spray produced clear improvements in several growth and physiological traits in tomato. The increase in the number of branches, flowers and fruits per plant in T₅ suggests an enhancement in vegetative activity and reproductive development. Flavonoids can influence hormone related pathways and may support better

shoot growth through improved cellular activity. These results corroborate earlier findings by Calvo *et al.* (2014) and Francesca *et al.* (2020) that flavonoid-based foliar sprays may promote branching and reproductive enhancement through systemic hormonal signalling mechanisms that may enhance cytokinin levels and reduce apical dominance. The higher fruit set in T₅ also reflects stronger source sink balance during flowering.

The observed yield benefits of CBL-treated plants can be explained by a combined effect of greater flowers, improved fruit set and increased photosynthetic activity during critical growth stages. Tomato has previously shown enhanced marketable gains with bio-stimulant programs involving seaweed extracts or amino acid formulations, demonstrating marked increases of 10-25% of marketable yield in treated compared to untreated controls (Vernieri *et al.*, 2005; Ertani *et al.*, 2013).

The improvements in chlorophyll content and photosynthetic rate in T₅ show that the flavonoid spray supported higher light use efficiency. Flavonoids can act as antioxidants within leaf tissues and help protect chloroplasts from oxidative stress, which allows sustained carbon assimilation under field conditions (Agati *et al.*, 2012). Similar results have been reported in tomato plants treated with plant based extracts under elevated temperatures, where enhanced SPAD values and improved gas exchange were noted (Francesca *et al.*, 2020). The higher photosynthetic rate in the present study is consistent with these reports and provides a likely physiological basis for the yield advantage in the flavonoid treatment.

The enhancement in photosynthesis may also relate to better stomatal regulation and mesophyll conductance and subsequent studies showing flavonoid-based foliar

spray improved gas exchange efficiency in tomato (Bulgari *et al.*, 2015).

The yield improvement in T₅ is consistent with earlier studies where natural extracts and related formulations increased reproductive growth and fruit production in tomato under stress or sub optimal environments (Francesca *et al.*, 2020). Higher yield in the present experiment can be attributed to increased fruit number, better fruit set and improved physiological activity during critical stages. Comparative treatments such as triacontanol and salicylic acid showed moderate improvements but did not reach the levels recorded in the flavonoid treatment. The untreated control remained lowest for all major yield determinants.

Soil organic carbon increased slightly in the flavonoid treated plots. This may be related to greater below ground activity and improved root functioning which can contribute to higher carbon deposition in the soil. Similar patterns of enhanced soil parameters have been reported when natural plant derived inputs stimulate rhizosphere processes and nutrient dynamics (Calvo *et al.*, 2014).

Disease incidence occurred in all treatments. The flavonoid spray did not reduce wilt or fruit borer damage, indicating that it does not replace plant protection inputs. However, plants treated with the flavonoid spray maintained better physiological vigour and sustained fruiting even under some disease presence. This aligns with reports that flavonoid compounds can support improved tolerance by enhancing antioxidant capacity or strengthening cellular integrity under stress conditions (Sharma *et al.*, 2019).

Overall, the experiment shows that the flavonoid enriched foliar spray improved several components of

tomato growth and productivity. The results support earlier findings that plant based formulations can enhance physiological efficiency and reproductive development in tomato. The favourable effects observed in this study indicate that such flavonoid solutions may serve as a useful addition to integrated crop management practices where the focus is on improving plant health and productivity with lower reliance on synthetic inputs.

CONCLUSION

The field evaluation of CropBioLife (CBL), a foliar spray based on bioflavonoids, resulted in favourable effects on parameters of growth, physiological aspects and yields of tomato in the rabbi-season in Andhra Pradesh. CropBioLife application at a rate of 4.0 mL L⁻¹ (T₃) resulted in substantially higher number of branches, flowers, fruits per plant, fruit set percentage, total yield per plant and relatively greater chlorophyll content and photosynthesis levels compared to the control and all-monoculture treatments. There were even indications of increased soil organic carbon levels in CBL-treated soil plots and it appears this bioflavonoid-based foliar spray has more pronounced impacts on production parameters than organics. No direct counter to fungal diseases was evident in the study; however, the increase in physiological vigour, coupled with the quality improvements, supports that the quicker time to physiological maturity will contribute to overall greater resilience of the crop. Overall, this study demonstrated the benefits of CBL, specifically the 4.0 mL L⁻¹ application rate, in diversified sustainable tomato production systems via productivity increases and quality improvements as well as probably positive soil health and physiological improvements as part of integrated pest and disease management practices.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest related to this research. No financial, personal or professional relationships influenced the design, execution or reporting of this study. All inputs used in the experiment were evaluated independently and without any commercial involvement.

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