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Influence of bio-enhancers and bio-fertilizers on growth and yield of winter season guava cv. L-49

Nitin Kumar Chouhan and V.K. Tripathi*

Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, 208 002, UP, India

ABSTRACT

An experiment was carried out to assess the impact of bio-enhancers and bio-fertilizers on the winter guava crop with the aim to improve the growth, flowering, and fruit yield. Different organic treatment combinations *viz.,* T_1-Control (no treatment), T_2-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + *Azotobacter* (50g/tree), T_3-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) + *Azotobacter* (50g/tree), T_4-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + *Azotobacter* (50g/tree), T_5-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + PSB culture (50g/tree), T_6-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) +PSB culture (50g/tree), T_7-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + PSB culture (50g/tree), T_8-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + PSB culture (50g/tree) +*Azotobacter*(50g/tree), T_9-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) +PSB culture (50g/tree) + *Azotobacter (50 g*/tree), T_{10}-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + PSB culture (50g/tree) + *Azotobacter* (50g/tree) were tested during the course of present study. Among the treatments, the highest fruit drop (65.01%) was in T_1 (control), whereas treatment T_9 was found most effective in enhancing the growth, flowering, fruiting and yield of winter guava, which showed the highest increase in the number of shoots per plant (14.79), shoot length (33.0), shoot diameter (4.12), number of leaves per shoot (36.91), total number of flowers per plant (515.24), number of fruits per plant (217.76), fruit retention (49.67%), fruit length (8.20cm) and yield (31.92kg) under north Indian conditions of U. P.

Key words: *Psidium guajava* L., organic mulch, biofertilizers, bioenhancers, yield, PCA.

INTRODUCTION

Guava (*Psidium guajava* L.), a most important fruit being a potential source of nutrients such as vitamin C, antioxidants, dietary fibres and essential minerals, with easily available at a reasonable price. The use of bio-enhancers such as Panchagavya, Amritpani and Jivamrit and biofertilizers *viz*., *Azotobacter*, is crucial for sustainable agriculture. These practices reduce the dependence on synthetic fertilizers, enhance soil fertility and crop productivity, minimize nitrogen losses, suppress soil-borne pathogens, and promote environmental sustainability by improving soil health, plant resilience and the health of aquatic ecosystems (Kravchenko *et al.,* 3). Panchagavya, a bio-enhancer, is made from five natural products sourced from indigenous desi cows: cow dung, cow urine, milk, curd, and ghee. These components contain essential microbes such as aerobic heterotrophic bacteria, lactic acid bacteria, yeast, fungi and anaerobic bacteria, which play an important role in enhancing plant growth and yield (Pathak and Ram, 5). Amritpani, which is prepared with components such as ghee, fresh cow dung, honey and water, is a significant bio-enhancer that can be easily made by farmers. It contains beneficial microorganisms such as Actinomycetes, *Pseudomonas*, phosphorus-solubilizing bacteria, *Azotobacter* and *Azospirillum*. Jivamrit is similar to Amritpani but includes additional ingredients like jaggery, pulse flour and banyan tree soil, enhancing its microbial diversity (Pathak and Ram, 5). *Azotobacter* fix atmospheric nitrogen, thereby significantly contributing to the nitrogen needs of crops and improving yields. Phosphate-solubilizing bacteria (PSB) like *Pseudomonas* and *Bacillus* convert non-available inorganic phosphate into a soluble form, enhancing phosphorus availability and crop yield (Tripathi *et al.,* 11).

The rising demand for sustainable agricultural practices has spurred greater interest in the use of organic inputs such as bio-enhancers and bio-fertilizers. These natural alternatives not only enhance plant growth and yield but also improve soil health while mitigating the environmental damage caused by chemical fertilizers. Guava, a key tropical fruit, can benefit substantially from these eco-friendly practices, making it an ideal fruit for sustainable cultivation. This study aims to evaluate the effects of bioenhancers and biofertilizers on the growth, flowering and fruit

*Corresponding author: drvktripathicsa@gmail.com

yield of winter season guava cv. L-49 to produce high yield of quality guava while ensuring health safety and environmental sustainability through the use of organic treatments.

MATERIALS AND METHODS

The research was conducted during 2022-23 and 2023-24 at the Kalyanpur Nursery, Department of Fruit Science, C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. Kanpur district is situated in a subtropical zone, between 25.26° and 26.58° North latitude and 79.31° and 80.34° East longitude, at an elevation of 135 meters above sea level. Various treatments *viz.*, T_1-Control (no treatment), T_2-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + *Azotobacter* (50g/tree), T_3-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) + *Azotobacter* (50g/tree), T_4-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + *Azotobacter* (50g/tree), T_5-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + PSB culture (50g/tree), T_6-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) + PSB culture (50g/tree), T_7-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + PSB culture (50g/tree), T_8-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Amritpani (20%) + PSB culture (50g/tree) + *Azotobacter* (50g/tree), T_9-FYM (10kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) + PSB culture (50g/tree) + *Azotobacter (50 g*/tree), T_{10}-FYM (10 kg/tree/year) + Organic mulch (Paddy) + Jivamrit (20%) + PSB culture (50g/tree) + *Azotobacter* (50g/tree) were applied on the guava. The experiment was laidout in Randomized Block Design with three replications. Foliar application of Panchagavya on plant canopy and drenching of Jivamrit and Amritpani in basal area of guava trees were done before and during flowering and fruit setting phase. To ensure through foliar coverage, 10-liter solution was administered using a pneumatic foot sprayer with a nozzle, targeting the entire foliage between 8:00 to 10:00 am. A high-legged stool was employed to facilitate complete drenching of the plant, including the upper portions. Paddy straw was used as mulch material around the root zone to prevent the spread of excess spray. Crop management followed regional agronomic recommendations specific to guava cultivation. Bio-fertilizers are also applied according to the specific treatment and were mixed with FYM and incorporated in the soil.

The observations were recorded on different traits, related to growth, flowering and yield attributes *viz.* number of shoots per plant, shoot length (cm), shoot diameter (cm), number of flowers per tree and number of leaves per shoot, number of fruits per plant, fruit drop (%), fruit retention (%), fruit length (cm) and fruit yield/tree. The number of shoots per plant was recorded after the final harvest and average was calculated. Shoot length was measured from five randomly selected shoots per tree and their average length was determined. Shoot diameter was measured at a specific point using calipers on five randomly selected shoots per tree and the average was calculated. Leaves from five randomly selected shoots per plant were counted after the final harvest and the average number of leaves per shoot was calculated.

The percentage of fruit drop was determined using the following formula:

$$\text{Fruit drop (\%)} = \frac{\text{Number of fruits at initial stage - Number of fruits retained at maturity}}{\text{Number of fruits at initial stage}} \times 100$$

The mean value of the number of flowers on selected five branches was counted and the number of flowers per tree was assessed. The percentage of fruit retention was worked out using the accompanying formula:

$$\text{Fruit retention (\%)} = \frac{\text{Total no. of fruits retained per determinate shoot till maturity}}{\text{Number of fruits set per determinate shoot}} \times 100$$

Five fruits were randomly selected from each treatment, and their length and diameter were measured at the time of harvesting using vernier calipers. The fruits from each picking were weighed using a top pan balance, and the total yield per plant was worked out in kilograms.

The collected data for each parameter were analyzed through analysis of variance (ANOVA) for a randomized block design using OPSTAT software, developed by H.A.U., Hissar, Haryana. The results were interpreted using the 'F' test, and treatment means were compared by calculating the critical difference (C.D.) at a 0.05 probability level. Duncan's Multiple Range Test (DMRT) was applied at $p<0.05$ to further compare the treatment means. This methodological approach ensured the accuracy and reliability of the results, with statistical validation confirming the significance of differences between treatments.

RESULTS AND DISCUSSION

The number of shoots per plant was significantly influenced by different treatment combinations of bio-enhancers and bio-fertilizers (Table 1). The highest number of shoots (14.79) was recorded in treatment T_9, showing a notable increase compared to untreated plants, where the lowest number of shoots per plant (8.66) was observed in the control treatment (T_1). Panchagavya contains natural growth hormones such as auxins, cytokinins, and gibberellins, which are known to stimulate plant growth and development. This effect has been demonstrated in previous studies as well (Krishnasamy *et al.,* 4). Additionally, photosynthetic bacteria enhance nitrogen availability to the leaves, a critical element for plant growth. These factors likely contributed to the increased plant height and number of branches, similar to results observed in cherry tomato plants. As compared to the non-treated plant (T_1), significantly increase the shoot length (33.00 cm) was noticed in T_9, whereas the minimum shoot length (19.98 cm) was recorded in T_1-control (Table 1). Bio-enhancer and biofertilizers significantly influences of the microbes residing in the rhizosphere, which enhance the mobilization of solutes to the roots and thereby improve overall tree growth. Nitrogen-fixing biofertilizers, particularly *Azospirillum* and *Azotobacter*, produce growth-promoting hormones such as IAA (Indole-3-Acetic Acid), which are absorbed by the roots and likely contribute to increased vegetative growth (Yadav *et al.*, 15).

Analysis of the data indicates an upward trend in shoot diameter for most treatments involving bio-fertilizers and bio-enhancers, with the maximum shoot diameter (4.12 cm) observed in T_9 (Table 1). In contrast, the minimum shoot diameter (2.27 cm) was recorded in T_1 (untreated). This improvement is attributed to the bio-mix promoting the synthesis of natural auxins, which facilitate cell division and elongation. This process ultimately enhances the number and length of sprouts, leading to greater carbohydrate accumulation and nutrient utilization, resulting in increased shoot girth. These findings are consistent with research on pomegranate stem cuttings (Yasser, 17). The maximum number of leaves per shoot (36.91) was recorded in T_9, whereas the minimum (20.99) was observed in the T_1-control treatment ((Table 1). Foliar application of Panchagavya is known to promote larger leaves and denser canopies (Somasundaram *et al.,* 7). Furthermore, biofertilizers enhance soil microbial populations, which support plant growth and productivity (Tripathi, 12). Panchagavya contains vitamins, amino acids and growth regulators such as auxins and gibberellins, along with beneficial microorganisms such as Pseudomonas, *Azotobacter*, and phosphorus-solubilizing bacteria (Singh *et al.*, 6), all of which contribute to improved plant growth. The highest flower count per plant (515.24) was observed in the treatment T_9 (Table 2), compared to all other treatments, including the control which produced the fewest flowers (404.93). These results suggest that the integration of Panchagavya and biofertilizers contributed to increased inflorescence per branch by enhancing crop growth, vigor and resistance to pests and diseases, boosting growth and production. Biofertilizers such as *Azotobacter* and organic manures like FYM provide balanced nutrition by biologically fixing nitrogen, solubilizing phosphate, and promoting growth with essential elements such as vitamins and hormones (Pathak and Ram, 5; Swaminathan *et al.*, 10). These findings are consistent with studies on strawberries, where an increase in flower numbers per plant was observed (Tripathi *et al.*, 13).

The maximum number of fruits per plant (217.76) was noted in T_9, whereas, minimum number of fruits per plant (111.41) was recorded under control (Table 2). The results indicate that the bio-enhancers and bio-fertilizers was significantly influenced the number of fruits per plant compared to control. This might be because of the expansion in the number of leaves which worked as an effective photosynthesis structure and produced high quantum of carbohydrates in the plant system. Further number of blossoms, which redounded progressed fruits per plant because of capacity of vermicompost in creating development hormones, enzymes, antifungal and antibacterial composites, which in turn improved attractive yield over different treatments. Salutary goods of *Azotobacter* were due to the obsession of atmospheric nitrogen and enhancement in this parameter. Similar findings additionally revealed by Yadav *et al.* (16) in strawberry. The data presented in Table 2 shows that the lowest fruit drop (50.33%) was observed in treatment T_9, while the highest fruit drop was recorded in the untreated guava plants (T_1). These results suggest that various combinations of bio-enhancers and biofertilizers are negatively correlated with fruit drop. In contrast, the control treatment (T_1-without any treatment) exhibited the highest fruit drop (Sourabh *et al.*, 8). Moreover, the percentages of fruit retention were significantly influenced by the different treatment combinations (Table 2). The maximum fruit retention (49.67%) was noted in T_9, while the minimum retention (34.99%) occurred in the control treatment (T_1). The application of biofertilizers and bio-enhancers positively correlated with increased auxin synthesis, promoting nutrient supply and balanced proportions from planting to harvest. These findings align with studies on guava (Godage *et al.*, 1) and strawberry (Tripathi *et al.*, 13).

The results clearly demonstrated that different combinations of biofertilizers and bio-enhancers had a significant impact on fruit length. The maximum fruit length (8.20 cm) was observed in treatment T_9, while the minimum fruit length (5.13 cm) was recorded in the T_1-control treatment (Table 2). The

Table 1. Effect of different treatments on growth characteristics of L-49 guava (pooled means for two seasons).

Treatment	Number of shoots/ plant	Shoot length (cm)	Shoot diameter (cm)	Number of leaves/ shoot
T_1	8.66h	19.98g	2.27i	20.99i
T_2	9.91g	22.36f	2.54h	23.74h
T_3	11.58e	25.62e	3.11f	26.91f
T_4	10.92f	23.10f	2.77g	25.56g
T_5	11.66e	26.97d	3.26e	29.88e
T_6	13.00d	29.11c	3.71c	33.91c
T_7	12.93d	27.62d	3.39d	31.99d
T_8	13.81c	31.43b	3.97b	35.57b
T_9	14.79a	33.00a	4.12a	36.91a
T_{10}	14.25b	31.66b	4.06ab	35.95ab
SE(d) $\pm$	0.160	0.488	0.046	0.495
C.D. $_{(0.05)}$	0.339	1.033	0.097	1.048

presence of beneficial microbes and nutrients in Panchagavya and Jivamrit, when applied both as foliar sprays and soil treatments, promoted plant growth by enhancing nutrient availability, cell division, metabolic activity, and carbohydrate accumulation, which ultimately increased the fruit length. Similar positive effects were also observed in strawberries with the application of *Azotobacter* and PSB (Tripathi *et al.*, 14). The experiment revealed that the highest yield per tree (31.92 kg) was recorded in treatment T_9, whereas the control treatment showed the lowest yield per tree at 12.54 kg (Table 2). These results indicate that the combinations of biofertilizers and bio-enhancers significantly influenced fruit yields. A positive correlation was observed with various applications of Panchagavya, Jivamrit, Amritpani, and other biofertilizers. These treatments enhance the availability of both major and minor nutrients and are abundant in beneficial microorganisms, particularly bacteria. The naturally occurring beneficial microorganisms, primarily bacteria and yeast, promote plant growth, metabolic processes, and resistance to pests and diseases (Swaminathan *et al.*, 10). Furthermore, these microorganisms improve the soil ecosystem and increase nutrient availability from source to sink, which lead to higher production and quality of various fruit crops. Similar findings were reported by Srivastava *et al.* (9).

The data on analysis of traits association, reflected in Fig. 1 showed that the number of shoots per plant was positively and significantly correlated to shoot length, shoot diameter, number of leaves per shoot, total number of flowers per plant, fruit retention, fruit length, fruit yield per tree at $P < 0.001$ % and was negatively associated with fruit drop at $P < 0.001$ %. The shoot length was observed positively correlated with many of the characters except non-fruit drop was found negatively correlated ($P < 0.001$%). All growth, flowering and yield parameters except fruit drop was positively correlated at $P < 0.001$ %. Number of leaves traits was positively correlated with shoots per plant, length, shoot diameter, total number of flowers per plant, fruit retention, fruit length, fruit yield per tree, at $P < 0.001$ %, while the fruit drop was negatively correlated at $P < 0.001$ %. The total number of flowers

Table 2. Effect of various treatments on flowering, fruiting and yield of L-49 guava (pooled means for two seasons).

Treatment	Number of flowers/ plant	Number of fruits/ plant	Fruit drop (%)	Fruit retention (%)	Fruit length (cm)	Yield (kg/tree)
T_1	404.93h	111.41j	65.01a	34.99g	5.13i	12.54j
T_2	420.09g	125.49i	61.99b	38.01f	5.56h	15.12i
T_3	436.66ef	141.43g	57.93c	42.07e	6.46f	17.91g
T_4	424.99fg	133.66h	60.80b	39.19f	6.01g	16.61h
T_5	446.99e	152.08f	56.08cd	43.92d	6.76e	19.70f
T_6	475.57c	175.16d	52.87ef	47.13bc	7.43c	23.55d
T_7	460.99d	164.41e	54.04de	45.96c	7.11d	21.60e
T_8	491.53b	186.41c	52.02efg	47.98ab	7.92b	25.68c
T_9	515.24a	217.76a	50.33g	49.67a	8.20a	31.92a
T_{10}	504.59ab	198.41b	51.58	48.42ab	8.08ab	28.42b
SE(d) $\pm$	6.35	2.62	1.04	0.80	0.12	0.28
C.D. $_{(0.05)}$	13.44	5.54	2.21	1.69	0.25	0.59

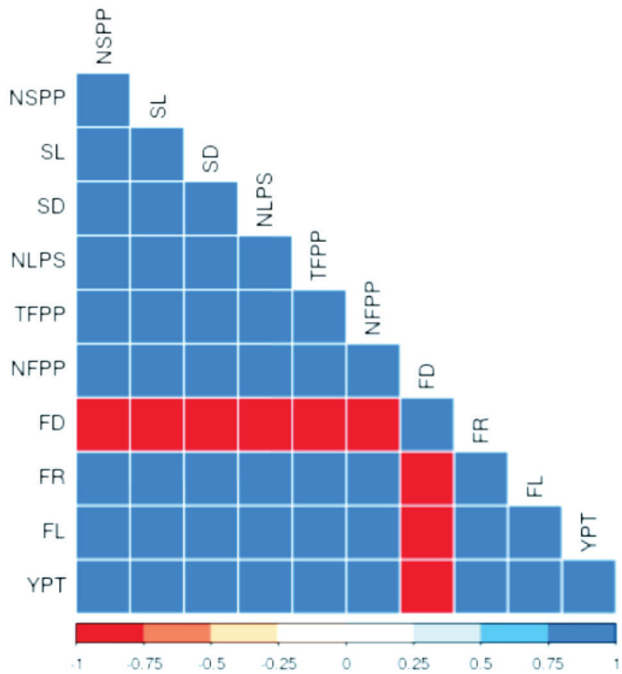

Fig. 1. Correlation exhibiting relationship among various attributes.

NSPP: No of shoots per plant, SL: Shoot length SD: Shoot diameter, NLPS: Number of leaves per shoot, NFPP: Total No. of flower per plant, NFPP: Number of fruits per plant, FD: Fruit drop, FR: Fruit retention, FL: Fruit length, YPT: Yield per tree

per plant was significantly positively correlated with all traits except drop, which one negatively correlated at *P < 0.001 %*. Like the total number of flowers per plant, the number of fruits per plant was positively correlated with all treatments, except fruit drop, which was negatively correlated at *P < 0.001* %. The fruit also positively correlated most of traits except fruit drop which of was highly negatively associated at *P < 0.001* % (***). Fruit length and fruit yield per tress was also positively correlated with shoot length, shoot diameter, number of leaves per shoot, total number of flowers per plant and fruit retention. The structure of a data set is studied using principal components analysis (PCA), a statistical method for multivariate analysis, to identify the processes influencing the scores of the variables present in the data. Several linear combinations of observable variables are created using principal component analysis (PCA) and these linear combinations are referred as components or factors. The variation pattern of vegetative and yields attributes response to bi-enhancers and bio-fertilizers was studied using principal components. The factors serve to condense the correlations present in the observed correlation matrix and possessed the capacity to precisely duplicate the observed matrix (Jixi *et al.*, 2). Out of nine PCs observed in the study, only two were reported significant due to Eigen values more than 1 which contributed 99.50% to total variations. Rest of the seven PCs Eigen values found less than 1 and non-significant for the study (Table 3).

PCA biplot analysis divided the traits into main and subgroups based on homogeneity and dissimilarity. Five sets of traits were identified, which were considered under PC1 and PC2. Most traits, such as the number of shoots per plant, shoot length, shoot diameter, fruit length, number of leaves per shoot and fruit retention in the west-north direction, were clustered under group I. Meanwhile, traits such as the number of flowers per plant and total number of fruits per plant in the west-south direction were grouped in cluster II, with fruit drop also categorized under group II. Notably, the PCA biplot indicated that groups I and II, which significantly contributed to PC1, were highly associated with the treatment T_8. Traits correlated with group III were aligned with PC2. The length and intensity of the vector in the biplot illustrated how well the traits were represented and how much they contributed to the principal components. Group I contributed more to PC1, followed by groups II and III. The parameters of groups I, II and III appeared to be independent of each other, based on the angles between the vectors derived from the central point of the biplot (Fig. 2). Therefore, the principal component

Table 3. Extracted eigenvalues and correlation values for vegetative parameters and fruit yield with the first two principal components (pooled means for two seasons).

Variables	Principles components	
	PC1	PC2
Extracted Eigenvalues	9.836	0.114
Explained variance (%)	98.362	1.142
Cumulative variance (%)	98.362	99.504
Traits		
NSPP: No of shoots per plant	0.992	-0.031
SL: Shoot length	0.997	-0.011
SD: Shoot diameter	0.996	-0.038
NLPS: Number of leaves per shoot	0.995	-0.066
NFPP: Total No. of flowers per plant	0.990	0.127
NFPP: Number of fruits per plant	0.988	0.146
FD: Fruit drop	-0.990	0.134
FR: Fruit retention	0.990	-0.134
FL: Fruit length	0.998	-0.038
YPT: Yield per tree	0.983	0.181

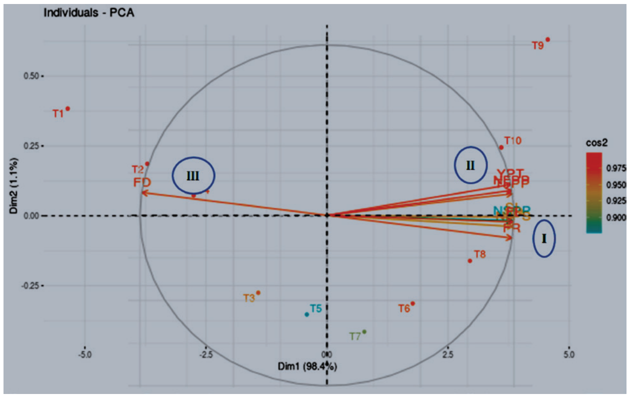

Fig. 2. Principal component analysis (PCA) of vegetative and yields traits.

analysis suggests that nutrient management practices influencing the vegetative traits along PC1 will be most effective for promoting crop growth and development, as most factors showed positive correlations. In contrast, PC2 contributed more towards yield per tree, particularly in group III. The experimental findings revealed that the most effective treatment was T_9, which combined FYM (10 kg/tree/year) + Organic mulch (Paddy) + Panchagavya (3%) + PSB culture (50g/tree) + *Azotobacter* (50g/tree), significantly increased shoot and leaf development, accelerated flowering and improved fruit yield. These results highlight the practical benefits of integrating organic treatments for sustainable guava production, promoting better soil health and nutrient availability and ultimately improving crop productivity and quality.

AUTHORS' CONTRIBUTIONS

Conceptualization of research (NKC); Designing of the experiments (VKT); Contribution of experimental materials (NKC); Execution of field/lab experiments and data collection (NKC, VKT); Analysis of data and interpretation (NKC, VKT); Preparation of the manuscript (NKC); review and editing (VKT).

DECLARATION

The authors declare no competing interests.

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