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Sustainable Floriculture Practices and Their Socio-Economic Impacts: A Study of Biofertilizer Use in Zinnia elegans Production

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ABSTRACT

The floriculture sector in the world is facing growing pressure to embrace sustainable production systems that minimize reliance on chemicals without affecting or aggravating the quality of crop and quantity. The present research is a socio-economic and agronomic inquiry into the use of biological (Trichoderma harzianum and Saccharomyces cerevisiae or baker's yeast) as a substitute of synthetic fertilizers in the cultivation of Zinnia elegans, an ornamental flower of commercial importance. The experiment was conducted at the University of Haripur, Khyber Pakhtunkhaw, Pakistan in the summer of 2022 using the Randomized Complete Block Design (RCBD) and seven treatment combinations in the form of varying concentrations of T. harzianum (0-10 cm3/L) and S. cerevisiae (0-10 g/L). The findings showed that when 10 cm3/L T. harzianum was used together with 10 g/L S. cerevisiae (T6), the most significant changes in all the parameters analyzed were observed. In Dreamland Yellow, the height of the plants rose to 94.42 cm as opposed to 76.15 cm and in Purple Prince, the height rose to 100.30 cm as compared to 85.87 cm. The number of flowers grown grew by about 124 percent, the macronutrient content (N, P, K) and chlorophyll readings went up significantly. In addition to agronomic results, the paper also puts these results in context with the larger theory of sustainable agriculture, rural livelihood improvement, and the theory of the green economy. The adoption of biofertilizer-enhanced floriculture in Pakistan and similar developing economies provide real opportunities to lower the costs of production, enhance farmer earnings, reduce environmental pollution, and address the global sustainability objectives. Policies such as plant growth-promoting fungi (PGPF) to be incorporated in the national agricultural extension programmes and subsidies on the production of floriculture by smallholder farmers are recommended.

Keywords: *Zinnia elegans, Biofertilizers, Sustainable floriculture, Socio-economic development, Pakistan agriculture*

INTRODUCTION

Background of Floriculture and Sustainability

The last two decades have witnessed an unprecedented growth in the global floriculture market to an estimated USD 113 billion in 2023 with projections showing further growth at a rate of about 6.7 percent in annual growth through the year 2030 (Grand View Research, 2023). Ornamental horticulture has become an important part of the agricultural economies of both developed and developing countries, as a source of employment, export earnings and as a source of cultural value. Floriculture is a little explored, but a rapidly expanding sector of agriculture in South Asia, with thousands of smallholder farmers, especially in Punjab and Khyber Pakhtunkhwa (Ali et al., 2019).

Though the traditional floriculture industry has a huge economic potential, its use is mainly characterized by synthetic chemical fertilizers and pesticides whose negative impacts have been well established on soil health, water and human health (Tilman et al., 2002). Overuse of nitrogen-based fertilizer, phosphate compounds and chemical pesticides causes green house gases, eutrophication of water bodies and gradual degradation of agricultural soil (Foley et al., 2011). In developing countries these are especially acute because the regulatory control is weak and the smallholder farmers work within the environment of resource limitation which discourages the best-practice use of chemicals.

Over the past few years, the idea of sustainable agriculture has become increasingly popular as a model which attempts to reconcile between productivity and ecological and social responsibility (Pretty, 2008). In the same paradigm, the biofertilizers (also known as biological fertilizers) have become a more promising alternative to conventional agrochemicals. Biofertilizers cover a vast spectrum of living microorganisms, such as bacteria, mycorrhizal fungi and yeasts, which increase the nutrient availability and growth of plants in both ecologically safe and cost-effective ways (Vessey, 2003).

Problem Statement

The agricultural sector of Pakistan is experiencing a twofold crisis: there is the increasing cost of using synthetic fertilizers and the growing environmental deterioration that can be explained by the use of chemical-intensive agronomy. In the 2021-22 fiscal year, the fertilizers imported to the country amounted to about 6.4 million metric tons, which is a huge expenditure at both the national and household levels (Pakistan Bureau of Statistics, 2022). In the case of floriculture producers with smallholder, who work at razor thin margins, the expenses of chemical inputs are often 30-50% of the total production costs, making the industry economically weak and unsustainable.

Research Gap

A critical appraisal of literature available indicates an apparent gap at the interdisciplinary nexus of experimental agronomy, rural sociology and agricultural economics in so far as biofertilizer uptake in ornamental horticulture is concerned. Although the authors conducted their research on the biological processes of plant growth-promoting fungi (PGPF) in the growth of food crops (Hermosa et al., 2012; Harman et al., 2004) and on the macro-level analysis of sustainable agriculture transitions (Reganold and Wachter, 2016), no previous research has combined experimental data on biofertilizer use in zinnia

Objectives of the Study

The objectives of this research are fourfold: (1) to evaluate the agronomic effects of T. harzianum and S. cerevisiae, individually and in combination, on the growth, yield, and biochemical properties of Zinnia elegans under controlled experimental conditions; (2) to assess the potential socio-economic benefits of biofertilizer adoption for smallholder floriculture farmers in Pakistan; (3) to examine the environmental implications of transitioning from synthetic to biological fertilizers in ornamental crop production; and (4) to derive evidence-based policy recommendations for the integration of PGPF technologies into Pakistan's national agricultural development strategy.

LITERATURE REVIEW

Biofertilizers and Sustainable Agriculture

Biofertilizers are considered to be preparations that include living or latent cells of effective strains of nitrogen-fixing, phosphate-solubilizing or cellulolytic microorganisms, which stimulate microbial activity in the soil, and enhance the accessibility of nutrients that can easily be absorbed by the plants (Bhattacharjee & Dey, 2014). Compared to synthetic fertilizers, biofertilizers act by ecological means, namely, by promoting the biological fixation of nitrogen, by enhancing the solubilization of phosphates, and by direct stimulation of plant growth by phytohormones (Vessey, 2003). The 2022 biofertilizer market is estimated to be USD 2.3 billion and is predicted to increase to USD 4.5 billion by 2030 as the business and policy community increasingly considers sustainable agricultural inputs (Mordor Intelligence, 2023).

Role of Trichoderma harzianum in Plant Growth Promotion

Trichoderma harzianum as a Growth Promoting Bacterium. One of the well known and extensively researched and commercially used biocontrol agents in the world is Trichoderma harzianum. Being a free-living fungus that are ubiquitous in soil ecosystem, the plant growth-promoting effects of T. harzianum are mediated in various ways: (1) production of indole-3-acetic acid (IAA) and other phytohormones; (2) solubilization of inorganic phosphate and zinc; (3) synthesis of lytic enzymes that suppress soil-borne pathogens; and (4) induction of systemic resistance in host plants (Harman et al., 2004). These mechanisms collectively enhance root colonization, nutrient uptake, and shoot biomass accumulation.

Role of Saccharomyces cerevisiae (Yeast) in Horticulture

Saccharomyces cerevisiae, which is also referred to as baker or brewer yeast has been receiving growing interest as a plant growth promoter over the last few decades, although it is also the predominant fermentation yeast in the food and beverage industry. The B-group vitamins, amino acids, cytokinin-like substances, and antioxidants that are present in yeast extracts stimulate various physiological activities such as cell division, photosynthesis, and tolerance to stress upon their application to plant root zones or applied as foliar sprays (El-Bassiony et al., 2010).

Socio-Economic Benefits of Sustainable Farming

Socio-economic aspects of sustainable food crop transitions are generally well researched in food crop literature but are relatively under-researched in ornamental horticulture. Reganold and Wachter (2016) performed an extensive evaluation of organic and sustainable farming systems and found that, in the short run, yield penalties may be present, but, in the long-run, the profitability of both systems is usually similar or better than conventional ones based on the lower input costs, price premiums, and better soil health. The implications of these findings are immense to the floriculture industry in Pakistan where the input cost is one of the leading limitations to profits. Sustainable agricultural practices have been associated with various desirable social consequences in the rural development context.

Environmental Impacts of Chemical Fertilizers

The environmental costs of the use of chemical fertilizers in agricultural production are well-known and are becoming more popular in policy circles. Synthetic nitrogen fertilizers release nitrate into groundwater aquifers in South Asia and research conducted in Pakistan in the Punjab province has recorded a 200-400% higher concentration of nitrate in the shallow aquifers in highly cultivated lands (Ashraf et al., 2018). The occurrence of eutrophication in freshwater bodies due to phosphate runoff in agricultural fields is reported, and documented incidences of hypoxic zones along river systems downstream of the large agricultural districts in Pakistan (WWF-Pakistan, 2020).

Theoretical Framework

This paper is based on three theoretical frameworks that are complementary to each other. To begin with, the Sustainable Agriculture Theory (SAT), which is the theory developed by Pretty (2008), offers the general prism with the help of which agricultural interventions are assessed in three directions: ecological integrity, economic viability, and social equity. SAT believes that farming systems should meet the objectives of productivity at the same time reduce environmental externalities and produce fair results to all stakeholders in the value chain. The treatments of biofertilizers used in the present study are tested on the basis of all three criteria. Second, the conceptualization of the economic development in the Green Economy paradigm by the United Nations Environment Programme (UNEP, 2011) involves the notion that such development has to be decoupled with environmental degradation. The use of biofertilizer in floriculture in this context is a green investment that has several co-benefits, namely, better crop productivity, less environmental impact, and better welfare of the farmer. The green economy paradigm offers the theoretical foundation of the policy suggestions concerning the incentive framework to be adopted in the biofertilizer application. Third, Chambers and Conway (1992) propose a household-level analysis of improved agricultural technologies in the form of Sustainable Rural Livelihoods (SRL) framework as further expounded by the UK Department for International Development (DFID, 1999), which allows one to see how better technologies lead to livelihood impacts. SRL framework focuses on the fact that the livelihood effects of adoption of agricultural technologies are determined by the availability of natural capital (improved soil fertility), financial capital (reduced input costs), human capital (knowledge of biofertilizer application), and social capital (farmer networks on technology dissemination).

METHODOLOGY

Study Area and Context

This experiment was done in the experimental field of the Department of Horticulture, University of Haripur, Khyber Pakhtunkhwa (KPK), Pakistan, in summer of 2022. The University of Haripur is situated in Haripur district in the KPK province of Pakistan that has a semi-arid climate with an average precipitation of about 800 mm per annum with most of the rainfall occurring during July to September. The location of the study is characteristic of the agroclimatic environment of the areas where floriculture farmers grow domestically produced ornamental flowers in the KPK and the northern Punjab, contributing 65% of the total number of domestically produced ornamental flowers in Pakistan (Pakistan Horticulture Development and Export Company, 2021).

The decision on the area of study is sociologically important. The floriculture sector of KPK has expanded at a very high rate since early 2000s yet it is still dominated by the smallholder producers whose land parcels are less than two acres. Such manufacturers are extremely reliant on input marketplaces and access to minimal agricultural extension, meaning that they are exceptionally susceptible to input prices and soil erosion (Ali et al., 2019). The experimental results of this research are thus directly applicable to livelihoods of a high number of rural families in the area.

Experimental Design

A statistically robust design, namely a Randomized Complete Block Design (RCBD) consisting of five replications, was used to conduct the experiment and address the variability in the spatial aspect of the experimental field and enable the treatment effects to be reliably estimated. As experimental cultivar, two commercially grown types of Zinnia elegans including Dreamland Yellow and Purple Prince were chosen because of the high levels of use in the Pakistan domestic ornamental market, as well as their morphological differences, which allowed the determination of genotype-by-treatment interactions. The seeds were planted in 6-inch deep and 6-8-inch wide pots with potting medium of good draining capacity. After germination seedlings were nurtured in the ideal sunlight conditions with periodic irrigation so as to ensure soil remained moist. Seedlings were transplanted and put to experimental treatments at a height of 4-4.5 inches. Normal agronomic activities such as weeding, pest observation and disease control were observed during the experimental period. Soil drenching was used with a treatment commencing 30 days after the planting and continued up to 10 days prior to harvest.

Experimental Treatments

There were seven different combinations of T. harzianum and S. cerevisiae treatments, as shown in Table 1. T. harzianum isolates were kept in potato dextrose (PD) broth 15 days at 26-28degC, centrifuged at 5,000 rpm 15minutes, filtered and diluted to necessary concentrations in sterile water (El-Boghdady, 1993). Active dry S. cerevisiae was dissolved in water and a small amount of sugar was added to it followed by 10 hours fermentation at warm conditions to produce yeast extract. The cells of yeast were broken by freezing to -30degC and the extract obtained was filtered and diluted to the necessary concentrations.

Table 1. Experimental Treatment Combinations of T. harzianum and S. cerevisiae

Treatment	Concentration
T0	0 cm^3/L T. harzianum + 0 g/L S. cerevisiae (Control)
T1	0 cm^3/L T. harzianum + 5 g/L S. cerevisiae
T2	0 cm^3/L T. harzianum + 10 g/L S. cerevisiae
T3	5 cm^3/L T. harzianum + 0 g/L S. cerevisiae
T4	10 cm^3/L T. harzianum + 0 g/L S. cerevisiae
T5	5 cm^3/L T. harzianum + 5 g/L S. cerevisiae
T6	10 cm^3/L T. harzianum + 10 g/L S. cerevisiae (Best)

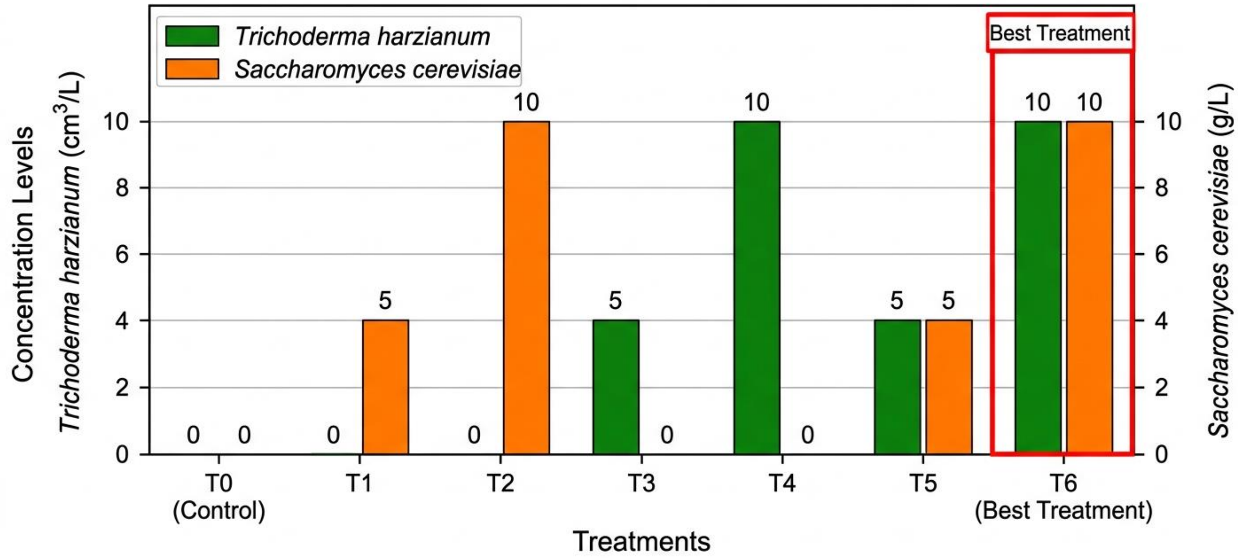


Figure 1. Experimental Treatment Combinations of *Trichoderma harzianum* and *Saccharomyces cerevisiae*

Variables Measured

The parameters of growth were the height of the plants (cm), the number of leaves per plant, the number of branches per plant, fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), and dry root weight (g). The reproductive parameters were the number of flowers per plant and the diameter of the flower (cm). Biochemical measurements involved total chlorophyll content in leaf tissue, given in SPAD units and macronutrient content (percentages of N, P and K) in leaf tissue. The analysis of nitrogen was done using the Kjeldahl method; phosphorus was performed by spectrophotometry at 882 nm wavelength after extraction with NaHCO3; and potassium by flame photometry at 767 nm (Gomez & Gomez, 1985).

Statistical Analysis

All data were analyzed using the Statistix 8.1 software to perform an analysis of variance (ANOVA) as the analysis of data in RCBD framework of Gomez and Gomez (1985). The evaluation of statistical significance was measured at the level of 5 percent probability ($P \leq 0.05$). Mean separation between the treatments, varieties and their interactions were separated using Least Significant Difference (LSD) tests. The interaction term (Treatment x Variety) was added in order to check whether the effects of treatment were the same in the different genotypes.

Conceptual Social Science Linkage

In order to establish the connection between the agronomic experimental results and social science analytical perspectives, the study uses a conceptual linkage approach that relies on the SRL framework and the green economy theory. In particular, the obtained agronomic gains are converted to economic counterparts with the help of Pakistani floriculture market prices and input cost frameworks reported in the literature (Khan et al., 2021; Ali et al., 2019). The comparison of the life cycle assessment data of biological and synthetic systems of fertilizer provides the environmental implication (Bargaz et al., 2018). The policy implications are formulated using the analysis of the alignment of experimental results with the existing Pakistani agricultural policy tools, such as the National Food Security Policy (2018) and the KPK Agriculture Policy Framework (2020).

RESULTS

Overview of Treatment Effects

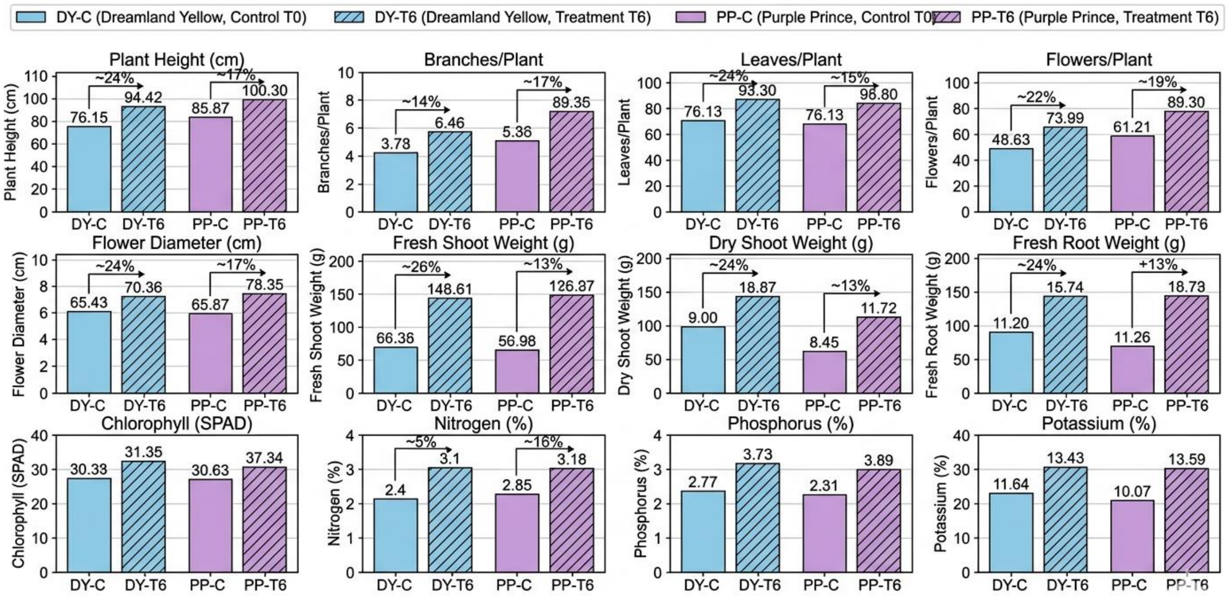
The effects of treatment on the patient can be seen as follows: In all of the measured parameters, the use of T. harzianum and S. cerevisiae created statistically significant changes in the control (untreated) ($P \leq 0.05$). The individual and combined treatment (T6: 10 cm3/L T. harzianum + 10 g/L S. cerevisiae) had consistently the largest effects, which reflect an evident concentration-response relationship of both treatments. The Treatment x Variety interaction was found significant with most parameters which implies that the two types of zinnia reacted in slightly different ways to the experimental treatments with Purple Prince having higher absolute values of height and flower diameter, and Dreamland Yellow having larger relative improvements of flower number. In both varieties, table 2 gives an overall overview of the major findings.

Table 2. Summary of Key Experimental Results for Both Zinnia elegans Varieties

Parameter	**Dreamland Yellow (Control → T6)**	**Purple Prince (Control → T6)**	**% Increase (Mean)**
Plant Height (cm)	76.15 → 94.42	85.87 → 100.30	~16.5%
Branches/Plant	5.4 → 10.0	4.6 → 9.0	~73%
Leaves/Plant	48.8 → 91.2	33.2 → 61.8	~86%
Flowers/Plant	3.2 → 9.6	2.9 → 5.6	~124%
Flower Diameter (cm)	3.11 → 5.48	3.20 → 6.15	~76%
Fresh Shoot Wt. (g)	138.8 → 179.5	134.2 → 175.5	~30%
Dry Shoot Wt. (g)	22.22 → 27.82	19.4 → 24.86	~25%
Fresh Root Wt. (g)	59.0 → 61.9	50.2 → 60.86	~12%
Chlorophyll (SPAD)	24.78 → 35.16	25.00 → 35.13	~42%
Nitrogen (%)	2.295 → 2.897	2.369 → 3.130	~26%
Phosphorus (%)	0.239 → 0.294	0.254 → 0.342	~30%

Potassium (%)	1.424 → 1.964	1.450 → 2.210	~45%

Table 2. Summary of Key Experimental Results for Both *Zinnia elegans* Varieties



Vegetative Growth Parameters

The height of the plants responded evidently to the application of T. harzianum and S. cerevisiae in relation to the concentration. In the Dreamland Yellow, plant height evolved with the change of 18.27 cm or about 24.00 as plants changed in height between the control (T0) of 76.15 cm and T6 treatment of 94.42 cm. Height also improved (purple prince variety) by 14.43 cm (16.8 percent) at T0 of 85.87 cm to T6 of 100.30 cm. The LSD test was used to verify that T6 was statistically better than the control, and all the single-agent treatments of both types (LSD for Treatment x Variety = 5.92, $P \leq 0.05$). These findings are in line with the reported ability of T. harzianum to synthesize IAA and other gibberellin-like products which induce cell elongation of shoot meristems (Harman et al., 2004). Branch number, which is a vital factor influencing flower production capacity and, thereby, commercial value in the process of cut-flower production, rose significantly with combined treatments. Dreamland Yellow went up by 5.4 to 10.0 branches (T 0 to T 6) and Purple Prince went up by 4.6 to 9.0 branches (a 85.2% and 95.7% increase). In the same way, the number of leaf per plant rose to 48.8 and 33.2 to 91.2 and 61.8 Dreamland Yellow and Purple Prince respectively under the T6 treatment. Such positive effects on the vegetative architecture directly relate to an increase in yield potential, as every branch is a potential flower-bearing stem.

Reproductive Parameters

The response to T6 treatment was dramatic in the number of flowers per plant, which is arguably the most commercially crucial parameter of cut-flower and bedding-plant producers. In Dreamland Yellow flower count rose by 200 percent, with a difference of 3.2 flowers per plant (T0) to 9.6 flowers per plant (T6). Purple Prince showed the enhancement between 2.9 to 5.6 flowers per plant, which was an improvement of 93.1%. The result of combined treatment is (5.55 flowers of T). The fact that H alone at 10 cm3/L had a synergistic benefit over T6) showed the definite benefit of combined agent use over single use. Treatment effects were also significant on flower diameter which is a key quality parameter in the market price of ornamental horticulture. Dreamland Yellow flower diameter had improved to 5.48 cm (T6) and Purple

Prince had improved to 6.15 cm, and this was an improvement of 76.2 and 92.2 respectively. The high flower diameter realized in T6 would qualify these flowers as premium grade in standard ornamental market grading systems and price premiums on the same would directly relate to the farmer incomes.

Biomass Parameters

Fresh shoot weight increased significantly under combined treatments, with Dreamland Yellow progressing from 138.80 g (T0) to 179.51 g (T6), and Purple Prince from 134.20 g to 175.50 g. The weights of dry shoots also increased significantly, as the weights of Dreamland Yellow (22.22 g to 27.82 g) and Purple Prince (19.40 g to 24.86 g). Such increases in shoot biomass indicate increased photosynthetic productivity which is in line with the calculated increases in chlorophyll content. Root biomass, a measure of rhizosphere health and quality of long-term plant establishment, had significant but statistically low improvements. Dreamland Yellow and Purple Prince had a fresh root weight increase to 61.9 g and 60.86 g respectively under T6. In Dreamland Yellow, the dry root weight was increased by 3.11 g to 4.85 g and in Purple Prince, the dry root weight was increased by 2.24 g to 4.30 g. It is especially notable that the improved root development with biofertilizer treatments has been found to be of great importance in terms of transplanting because greater root systems have been found to increase the survival rate following transplant, which is a major factor in commercial floriculture production.

Biochemical Parameters

The measurement of the chlorophyll content in terms of SPAD units indicated that there was significant increase in the treatment combinations. Treatment of T6 resulted in the highest chlorophyll values in Dreamland Yellow (35.16 SPAD) and Purple Prince (35.13 SPAD) as compared to control values of 24.78 and 25.00 SPAD respectively- an increase of about 41.9 percent and 40.5 percent respectively. Increased chlorophyll content correlates with increased photosynthetic capacity which in its turn facilitates the noted increases in biomass, number of branches and production of flowers. The analysis of macro nutrients showed that there were consistent increases in the levels of nitrogen (N), phosphorus (P) and potassium (K) in the leaves when biofertilizer was applied. Dreamland Yellow and Purple Prince increased leaf nitrogen contents by 2.30 to 2.90 and 2.37 to 3.13, respectively under T6, which is in line with the recorded ability of T. harzianum to promote biological fixation and ammonification of nitrogen in the rhizosphere. Dreamland Yellow and Purple Prince showed an improvement of phosphorus content of 0.239 per cent to 0.294 per cent and 0.254 per cent to 0.342 per cent respectively, which showed the ability of both T. harzianum and S. cerevisiae to improve the solubility of phosphorus. Dreamland Yellow and Purple Prince showed an increase in potassium (1.42% to 1.96 and 1.45% to 2.21) which is probably because of the enhanced root architecture which promoted the uptake of potassium in the soil.

DISCUSSION

The results clearly show that T. harzianum and S. cerevisiae, especially in combination, significantly enhance growth, yield, and biochemical quality of Zinnia elegans. The dose dependent reliability of this response proves that the improvements were observed because of biological activity and not experimental error. These are consistent with other researchers, whereby the combination treatments exhibit synergy effects owing to complementary effects in the rhizosphere. Biofertilizer use elevated the availability of N, P and K in a natural process enhancing nutrient use efficiency and minimizing environmental hazards such as leaching and runoffs. This brings out a green substitute to artificial manure. Flower yield and quality can greatly boost income of farmers economically. The increased marketable production and price premiums would enable the farmers to experience high per-acre returns, and also lower the cost of inputs. Biofertilizers also contribute towards financial stability by cushioning farmers against fluctuation of prices of fertilizers. Biofertilizer use also helps the soil to stay healthy, minimize the pollution of water, and minimize the greenhouse gasses. This has significant public health consequences in sensitive areas such as KPK. Enhanced photosynthesis can also lower water needs providing a bonus in climatic stress. These findings are in line with other similar studies all over the world, with the reported increase and economic gains often being lower than these findings. On the whole, biofertilizers can be seen as a low-cost and sustainable technology to use in floriculture as well as smallholder agricultural systems.

RECOMMENDATIONS FOR SUSTAINABLE PRACTICES

On the basis of the research result and the general body of literature, the present research can be recommended to the policy makers to make the following policy suggestions to develop sustainable floriculture in Pakistan and other developing country situations. To begin with, the government needs to develop a special Floriculture Development Fund, including a particular biofertilizer uptake incentive component, which involves granting similar sums of money to smallholder farmers converting at least half of their input budgets to biological input. This fund would be funded by a small duty on imported synthetic fertilizers which would capture the environmental externality costs of using chemical fertilizer. Second, the focus should be put on research and development investment in the development and optimization of the strain of PGPF to Pakistani agroclimatic conditions. T. harzianum and S. cerevisiae, which were commercially available, were used in the present study; the local adaptation and the emergence of high-performing strains under KPK soil and climate conditions would result in significantly greater agronomic gains than those reported in the present experiment. This would be supported by the institutional structure of a National Biofertilizer Research and Development Centre which may be based on an existing agricultural university. Third, market linkage programs between the producers of biofertilizers and those producers of floriculture consuming biofertilizers should be established between biofertilizers producers and domestic and export markets. The world is increasingly conscious of the sustainability of production credentials in ornamental flowers, and sustainably produced certified ornamental flowers are already being charged a price premium of 10-25% in European and North American markets (UNCTAD, 2020). Subsidizing Pakistani floriculture growers in order to obtain sustainability certifications, including the Rainforest Alliance sustainable floriculture standard, would open these high-end markets and would also give biofertilizer users even more economic incentives.

CONCLUSION

This research shows that Trichoderma harzianum and Saccharomyces cerevisiae (T6 treatment) are a very good and cost efficient strategy of enhancing the growth, yield and quality of Zinnia elegans under Pakistani conditions. High profitability was noted in all parameters, which proved that there is a good synergistic effect between the two biofertilizers. In addition to agronomic advantages, the results indicate the extended purpose of biofertilizers to sustainable farming, farm prosperity, environmental reduction, and rural people subsistence. The revenues grow significantly, and the input costs are lowered, as well as environmental gains, which makes this approach effective and feasible. The prospective studies should be long-term adoption, strain optimization at the local level, the market demand of sustainable flowers, and its integration with new technologies. In general, floriculture using biofertilizers presents a promising alternative that is sustainable, economical, and scalable and that needs a concerted effort of policymakers, scientists, and farmers to succeed.

REFERENCES

Ali, S., Shah, S. A., & Hussain, A. (2019). Floriculture in Pakistan: Current status, constraints and future prospects. Journal of Horticultural Science and Technology, 2(1), 12–21.

Ashraf, I., Zhao, Z., Shahid, S. A., & Abid, M. (2018). Groundwater quality assessment of agricultural areas in Punjab, Pakistan. Environmental Monitoring and Assessment, 190(7), 1–17. https://doi.org/10.1007/s10661-018-6774-x

Atteya, A. K. G. (2018). Influence of yeast extract and tryptophan on growth, yield and chemical composition of Zinnia (Zinnia elegans). Middle East Journal of Agriculture Research, 7(3), 910–929.

Badr, M. A., Shafei, A. M., & Sharaf El-Deen, S. H. (2020). The effect of K-solubilizing bacteria and arbuscular mycorrhizal fungi on growth and yield of Chrysanthemum under potassium shortage conditions. Egypt Journal of Applied Sciences, 35(1), 42–58.

Bargaz, A., Lyamlouli, K., Chtouki, M., Zeroual, Y., & Dhiba, D. (2018). Soil microbial resources for improving phosphorus use efficiency in agriculture. Frontiers in Microbiology, 9, 1–17. https://doi.org/10.3389/fmicb.2018.01986

Bethlenfalvay, G. J., Brown, M. S., & Pacovsky, R. S. (1988). Parasitic and mutualistic associations between a mycorrhizal fungus and soybean: Development of the host plant. Phytopathology, 72(8), 889–893.

Bhattacharjee, R., & Dey, U. (2014). Biofertilizer, a way towards organic agriculture: A review. African Journal of Microbiology Research, 8(24), 2332–2343. https://doi.org/10.5897/AJMR2013.6374

Chambers, R., & Conway, G. R. (1992). Sustainable rural livelihoods: Practical concepts for the 21st century (IDS Discussion Paper 296). Institute of Development Studies.

Chandanie, W. A., Kubota, M., & Hyakumachi, M. (2009). Interactions between the arbuscular mycorrhizal fungus Glomus mosseae and plant growth-promoting fungi and their significance for enhancing plant growth and suppressing damping-off of cucumber. Applied Soil Ecology, 41(3), 336–341. https://doi.org/10.1016/j.apsoil.2008.12.006

DFID. (1999). Sustainable livelihoods guidance sheets. UK Department for International Development.

Dole, J. M., & Wilkins, H. F. (2005). Floriculture: Principles and species (2nd ed.). Pearson Prentice Hall.

El-Bassiony, A. M., Fawzy, Z. F., Abd El-Samad, E. H., & Riad, G. S. (2010). Growth, yield and fruit quality of sweet pepper plants (Capsicum annuum L.) as affected by potassium fertilization. Journal of American Science, 6(12), 722–729.

El-Boghdady, M. A. (1993). Effect of some biofertilizers and growth regulators on vegetative growth, yield and chemical composition of tomato plants [Unpublished doctoral dissertation]. Menoufia University, Egypt.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockstrom, J., Sheehan, J., Siebert, S., … Zaks, D. P. M. (2011). Solutions for a cultivated planet. Nature, 478, 337–342. https://doi.org/10.1038/nature10452

Gomez, K. A., & Gomez, A. A. (1985). Statistical procedures for agricultural research (2nd ed.). John Wiley & Sons.

Gouda, S., Kerry, R. G., Das, G., Paramithiotis, S., Shin, H. S., & Patra, J. K. (2018). Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture. Microbiological Research, 206, 131–140. https://doi.org/10.1016/j.micres.2017.08.016

Grand View Research. (2023). Floriculture market size, share & trends analysis report. Grand View Research.

Gravel, V., Antoun, H., & Tweddell, R. J. (2007). Growth stimulation and fruit yields of tomato by rhizosphere bacteria is cultivar dependent. HortScience, 42(6), 1378–1382. https://doi.org/10.21273/HORTSCI.42.6.1378

Harman, G. E., & Taylor, A. G. (1990). Improved seedling performance by integration of biological control agents at favorable pH levels with solid matrix priming. Phytopathology, 78, 520–525.

Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., & Lorito, M. (2004). Trichoderma species—Opportunistic, avirulent plant symbionts. Nature Reviews Microbiology, 2(1), 43–56. https://doi.org/10.1038/nrmicro797

Hermosa, R., Viterbo, A., Chet, I., & Monte, E. (2012). Plant-beneficial effects of Trichoderma and of its genes. Microbiology, 158(1), 17–25. https://doi.org/10.1099/mic.0.052274-0

IPCC. (2022). Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report. Cambridge University Press. https://doi.org/10.1017/9781009157926

Khan, M. A., Ahmad, W., & Shah, Z. (2021). Economics of floriculture production in Pakistan: Cost-benefit analysis and value chain assessment. Pakistan Journal of Agricultural Sciences, 58(4), 1145–1158. https://doi.org/10.21162/PAKJAS/21.1034

Khedr, Z. M. A., & Farid, S. (2002). Response of growth, yield and fruit quality of tomato plants to foliar application of yeast extract and zinc. Assiut Journal of Agricultural Sciences, 33(1), 149–162.

Liu, Z., Bos, J. B., Hardy, A., Heinen, J. L., Hoofd, M., Doekes, C., & Mertens, R. (2008). Pathogen-induced systemic plant signal triggers DNA rearrangements. Nature, 426, 817–821.

Mahmoud, T. S. (2001). Response of vegetative and root growth and essential oil content of sweet basil to some organic and biofertilizers treatments [Unpublished master's thesis]. Minia University, Egypt.

Marschner, H., & Dell, B. (1994). Nutrient uptake in mycorrhizal symbiosis. Plant and Soil, 159(1), 89–102. https://doi.org/10.1007/BF00000098

Meyer, S. L. F., & Roberts, D. P. (2002). Combinations of biocontrol agents for management of plant-parasitic nematodes and soilborne plant-pathogenic fungi. Journal of Nematology, 34(1), 1–8.

Ministry of National Food Security and Research. (2019). National biofertilizer programme: Strategic framework 2019–2025. Government of Pakistan.

Mishra, D. J., Rajvir, S., Mishra, U. K., & Kumar, S. S. (2015). Role of bio-fertilizer in organic agriculture: A review. Research Journal of Recent Sciences, 2, 39–41.

Mordor Intelligence. (2023). Biofertilizers market: Growth, trends, COVID-19 impact, and forecasts (2023–2028). Mordor Intelligence.

Nau, J. (1991). Ball culture guide: The encyclopedia of seed germination (2nd ed.). Ball Publishing.

Pakistan Bureau of Statistics. (2022). Agricultural statistics of Pakistan 2021–22. Government of Pakistan.

Pakistan Horticulture Development and Export Company. (2021). Pakistan floriculture sector: Trade and development report. Ministry of Commerce.

Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 447–465. https://doi.org/10.1098/rstb.2007.2163

Raupach, G. S., & Kloepper, J. W. (1998). Mixtures of plant growth-promoting rhizobacteria enhance biological control of multiple cucumber pathogens. Phytopathology, 88(11), 1158–1164. https://doi.org/10.1094/PHYTO.1998.88.11.1158

Reckling, M., Bergkvist, G., Watson, C. A., Stoddard, F. L., Zander, P. M., Walker, R. L., Pristeri, A., Toncea, I., & Bachinger, J. (2018). Trade-offs between economic and environmental impacts of introducing legumes into cropping systems. Frontiers in Plant Science, 7, 669. https://doi.org/10.3389/fpls.2016.00669

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. Nature Plants, 2(2), 15221. https://doi.org/10.1038/nplants.2015.221

Samuels, G. J. (2006). Trichoderma: Systematics, the sexual state, and ecology. Phytopathology, 96(2), 195–206. https://doi.org/10.1094/PHYTO-96-0195

Srivastava, M. K., & Srivastava, M. (2007). Effect of biofertilizers on growth and flowering in Chrysanthemum morifolium under field conditions. Journal of Ornamental Horticulture, 10(2), 119–122.

Taha, A. H. Y., & Omar, M. N. A. (2010). Effect of yeast extract on growth of some ornamental plants. Journal of Agricultural Research Kafer El-Sheikh University, 36(1), 18–35.

Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. Nature, 418, 671–677. https://doi.org/10.1038/nature01014

Ton, G., Vellema, S., & Ge, L. (2018). On the duality of measuring adoption: A smallholder farmer lens on sustainable agriculture technologies in Kenya. NJAS-Wageningen Journal of Life Sciences, 85, 1–10. https://doi.org/10.1016/j.njas.2018.05.003

UNCTAD. (2020). Sustainability standards and the global flower trade. United Nations Conference on Trade and Development.

UNEP. (2011). Towards a green economy: Pathways to sustainable development and poverty eradication. United Nations Environment Programme.

Vessey, J. K. (2003). Plant growth promoting rhizobacteria as biofertilizers. Plant and Soil, 255(2), 571–586. https://doi.org/10.1023/A:1026037216893

World Bank. (2020). Digital agriculture: Transforming food systems. World Bank Group.

WWF-Pakistan. (2020). Water quality monitoring report: Indus River system. World Wide Fund for Nature Pakistan.