

SURVEY ON SUSTAINABLE PROMOTION OF NUTRITIONAL STATUS OF CROPS

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Abstract

Sustainable plant nutrition is essential for maintaining soil fertility and minimizing environmental impacts. This study evaluates farmers' perceptions, challenges, and adoption of sustainable fertilization practices through a structured questionnaire. Results indicate that crop rotation is the most preferred method, while a combination of chemical and organic fertilizers is widely used. Despite moderate effectiveness, concerns about environmental impact are high, yet adoption of mitigation measures remains limited. Financial constraints, particularly the high cost of organic fertilizers, are the main barriers to sustainability. Most respondents rely on fertilizer manufacturers for information, with lower engagement in scientific research. Strong interest in training exists, though accessibility issues persist. Spearman correlation analysis highlights links between fertilization practices, awareness, and sustainability actions. Principal Component Analysis identifies key factors influencing farmers' decisions, including financial support and knowledge accessibility. The findings emphasize the need for subsidies, expert collaboration, and improved information dissemination to promote sustainable fertilization.

Key words: environmental impact, soil fertility, principal components analysis, trends.

INTRODUCTION

Sustainable plant nutrition is essential for maintaining soil fertility, improving crop yields, minimizing environmental impacts and creating suitable context for food security. It also plays an essential role in reducing the environmental footprint of agricultural activities (Lin et al., 2015; Muhammad et al., 2019). According to current global tendencies, it is considered that the agricultural food systems yields should align with sustainable development aims, and promote human, and animal health (El-Ramady et al., 2020; Six, 2011; White & Brown, 2010).

It involves the dissemination of knowledge, implementation of best practices, and support for policies that encourage the adoption of eco-friendly fertilization methods (Meisterling et al., 2009).

As agricultural practices evolve, the balance between productivity and sustainability becomes increasingly important, requiring a shift toward integrated fertilization strategies that combine chemical and organic inputs (Chandel et al., 2024). While crop rotation and controlled fertilization have been widely adopted, challenges such as high costs, limited awareness,

and accessibility to sustainable alternatives continue to be critical points in the widespread implementation of environmentally friendly practices (Atz et al., 2019; Godfray et al., 2010; Gomeiro et al., 2011).

Fertilization practices are limitative in soil health and nutrient availability, but excessive reliance on chemical products has raised concerns about soil degradation, water contamination, and greenhouse gas emissions (Lal, 2015; Savci, 2012). Consequently, regenerative agriculture and organic fertilization are gaining attention as viable solutions, though their adoption remains limited due to financial constraints and a lack of technical knowledge (Khangura et al., 2023; Schreefel et al., 2020). Additionally, the primary sources of information on plant nutrition, predominantly fertilizer manufacturers, may influence farmers' choices, limiting exposure to scientific research and sustainable alternatives. Understanding farmers' perceptions and challenges in adopting sustainable fertilization methods is critical for designing effective policies and support programs (Adnan et al., 2019; Sun et al., 2022). This study aims to analyze the current trends in plant nutrition practices, assess the awareness of

sustainability issues, and identify the key factors influencing the adoption of regenerative fertilization strategies. By evaluating the relationships between fertilization practices, environmental concerns, and access to knowledge, this research seeks to provide insights that can guide future initiatives in promoting sustainable agricultural development.

MATERIALS AND METHODS

To emphasize the role of sustainable promotion of plant nutritional status in enhancing production of farmers focused on vegetal production a survey was conducted, during April - October 2024. Data were collected through a structured questionnaire, which included multiple-choice questions designed to capture respondents' preferences, awareness, and constraints in adopting sustainable fertilization practices. The questionnaire covered key topics such as plant nutrition methods, fertilizer types, effectiveness evaluation, environmental concerns, information sources, training interest, and perceived barriers.

The survey targeted agricultural practitioners, including farmers, agricultural consultants, students in agronomy, and researchers, to ensure a diverse representation of expertise and perspectives. The sample was selected using a stratified random sampling approach, ensuring coverage of different farm sizes and cultivation practices, including conventional and organic farming. The questionnaire was distributed through direct interviews, with a total of 400 valid responses collected. The sample size was calculated using the Cochran formula (<https://www.statisticshowto.com/probability-and-statistics/find-sample-size/>).

The collected data were analyzed using descriptive statistics to determine response frequencies and trends. To identify relationships between variables, Spearman's rank correlation coefficient was applied, assessing the associations between fertilization practices, environmental concerns, and access to knowledge. Principal Component Analysis (PCA) was employed to reduce data dimensionality and identify key factors influencing farmers' decisions regarding plant nutrition. PCA opportunity was tested by applying the Bartlett and Keiser - Meyer - Olkin

(KMO) tests (Merce & Merce, 2009). Statistical analyses were performed using Statistica v.8 for windows.

RESULTS AND DISCUSSIONS

Equipping farmers globally with crop rotation management tools could be a generous solution in achieving the sustainable development goals (Schöning et al., 2023). Crop rotation practices are the most preferred method, with 65% of respondents using this approach (Figure 1). This suggests that many farmers recognize the long-term benefits of crop rotation in enhancing soil fertility and plant nutrition. We consider that more awareness and education programs could encourage farmers to adopt organic fertilizers and biostimulants. We also consider that policymakers and agricultural support programs could incentivize the adoption of organic methods to improve soil health and reduce dependency on chemical fertilizers.

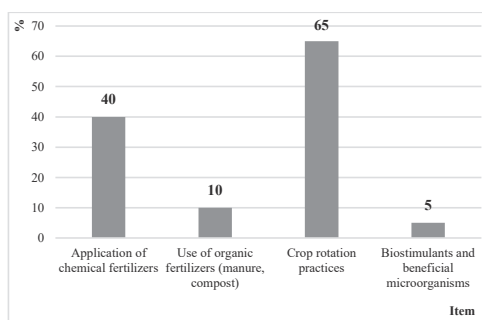


Figure 1. The respondents' opinions concerning the methods used to improve plant nutrition

There are studies showing that applying a combination of chemical and organic fertilizers enhances soil quality, supports plant growth, and increases yield compared to using chemical fertilizers alone (Wan et al., 2021). A combination of both chemical and organic fertilizers is the most commonly used approach, adopted by 50% of respondents (Figure 2). This indicates a balanced approach to plant nutrition, leveraging the benefits of both synthetic and natural inputs. The preference could suggest that many respondents recognize the advantages of integrating organic matter for soil health while still relying on synthetic fertilizers for immediate plant nutrition.

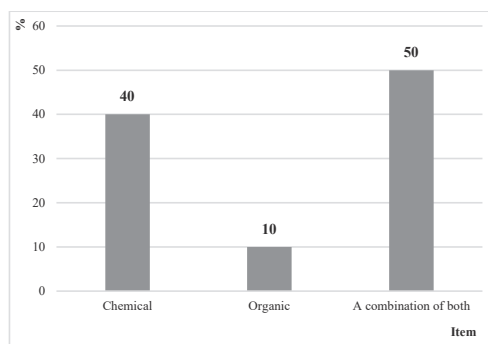


Figure 2. The respondents' opinions concerning the fertilizers used most often

Majority of interviewed subjects, 90% respectively, consider their plant nutrition practices to be moderately effective, indicating that while they observe positive results, there is still potential for improvement, while only 10% rate their practices as very effective (Figure 3). It results that few practitioners feel completely confident in their approach, and none of the respondents consider their methods ineffective, implying that all observe at least some benefits from their strategies, though further optimization and innovation could enhance overall effectiveness.

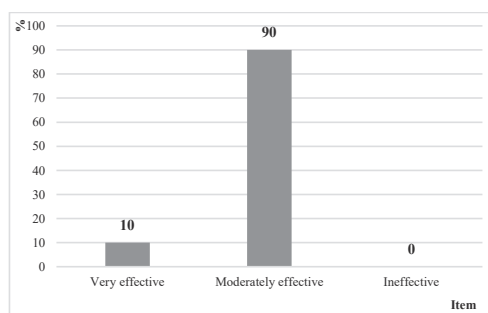


Figure 3. The respondents' opinions concerning the evaluation of the effectiveness of plant nutrition practices

90% of respondents express concern about the environmental impact of fertilization, indicating a high level of awareness regarding sustainability issues in agricultural practices (Figure 4). Only 10% do not share this concern, suggesting that although most acknowledge the potential risks associated with fertilization, there is still a small proportion that may require further information or motivation to adopt more environmentally friendly approaches.

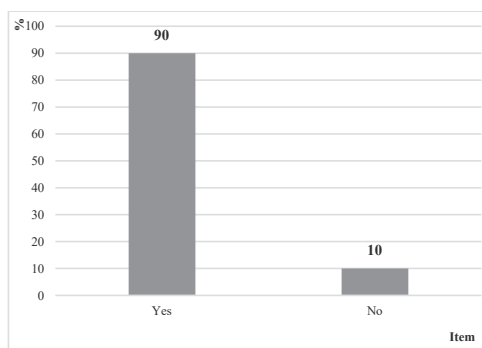


Figure 4. The respondents' opinions regarding the concerns about the environmental impact of fertilization

A half of the respondents have not yet taken any measures to minimize the negative impact of fertilization on soil and water, suggesting a significant gap in the adoption of sustainable practices (Figure 5). 35% implement controlled application of fertilizers, reflecting a more precise approach to nutrient management, only 10% alternate fertilizer types to reduce chemical dependency, and a minimal 5% use soil sensors to monitor nutrients. These findings suggest the need for greater awareness and accessibility to advanced monitoring technologies.

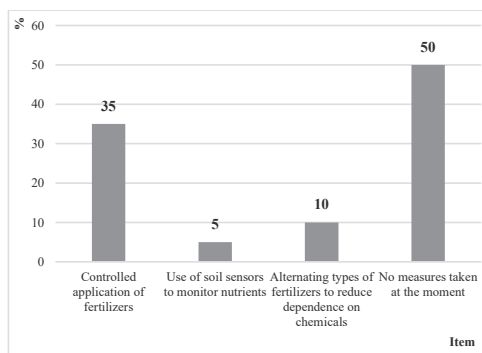


Figure 5. The respondents' opinions concerning the measures to minimize the negative impact of fertilization on soil and water

Majority of interviewed subjects, 80%, have only partial awareness of the benefits of regenerative agriculture for plant nutrition, indicating that while some knowledge exists, there is still a need for more comprehensive education and outreach (Figure 6). 15% are fully aware, suggesting a smaller group actively engaged with these principles, and only 5% have no awareness, showing that most respondents

recognize at least some aspects of regenerative agriculture but may require further guidance to fully integrate its practices.

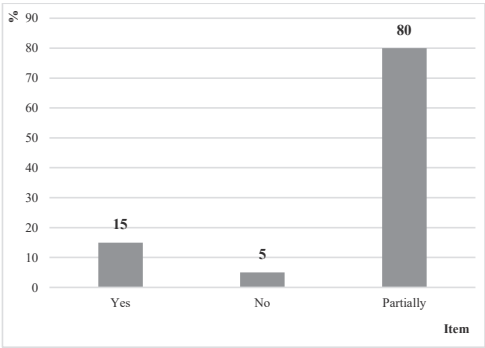


Figure 6. The respondents’ opinions concerning the awareness of the benefits of regenerative agriculture for plant nutrition

60% of questioned subjects rely on fertilizer manufacturers as their primary source of information about plant nutrition and fertilization, suggesting a strong influence of industry-driven knowledge, while 30% seek advice from agricultural consultants (Figure 7). 20% depend on their own experience, reflecting a hands-on learning approach, 15% obtain information from researchers and universities, showing a relatively lower engagement with scientific research, and only 10% use the internet and social media, suggesting limited reliance on digital sources for agricultural knowledge.

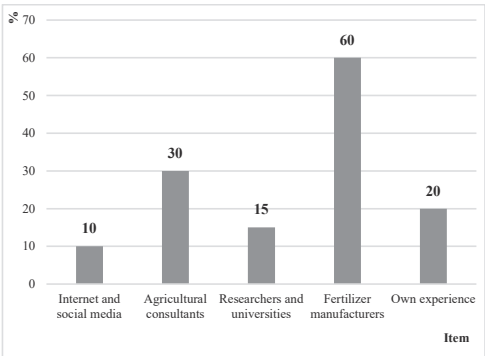


Figure 7. The respondents’ opinions concerning the sources of information about plant nutrition and fertilization

A proportion of 75% respondents, express interest in participating in training or workshops on sustainable crop fertilization, indicating a

strong willingness to enhance their knowledge and adopt improved practices (Figure 8). In the meantime, 20% are open to the idea but consider cost and availability as determining factors, suggesting that accessibility plays an important role in participation, and only 5% are not interested.

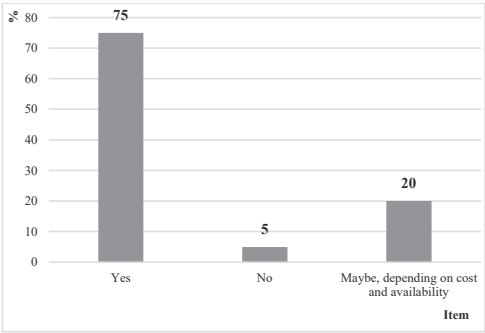


Figure 8. The respondents’ opinions concerning the interest in participating in training or workshops on sustainable crop fertilization

Majority of respondents, 80%, respectively, identify the high costs of organic fertilizers as the main challenge in adopting sustainable fertilization practices (Figure 9). This finding could suggest that financial constraints are a significant barrier. 20% of interviewed persons mention the lack of clear information, suggesting that improved access to knowledge and guidance could facilitate adoption, and only 10% report encountering no challenges. The responses show that most respondents face obstacles that hinder the transition to more sustainable fertilization methods.

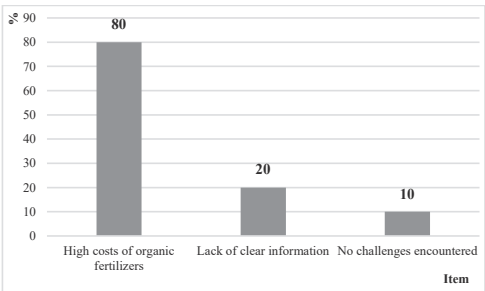


Figure 9. The respondents’ opinions concerning the challenges faced in adopting sustainable fertilization practices

90% of the questioned subjects consider financial support or subsidies as the most

necessary form of assistance for adopting more sustainable practices, while 25% emphasize the importance of collaboration with experts in the field, and 20% express the need for both access to information and practical guides as well as access to innovative products (Figure 10). These responses suggest the major role of technical guidance.

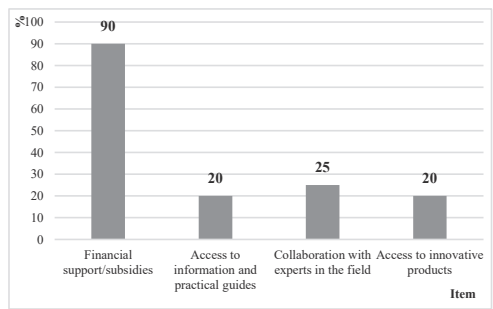


Figure 10. The respondents’ opinions concerning the support needed to adopt more sustainable practices

The simple Spearman correlations between various variables related to the sustainable promotion of plant nutritional status, showing that the methods used to improve plant nutrition

(Var1) exhibit a moderate positive correlation with the evaluation of plant nutrition effectiveness (Var3) and concerns about the environmental impact of fertilization (Var4), suggesting that better nutrition practices are linked to higher awareness and perceived effectiveness (Table 2). The fertilizers used most often (Var2) have strong negative correlations with measures to minimize the negative impact of fertilization (Var5), awareness of regenerative agriculture benefits (Var6), and sources of information (Var7), indicating that reliance on certain fertilizers may be associated with lower engagement in sustainable strategies. The strong positive correlations between measures to minimize fertilization impact (Var5), awareness of regenerative agriculture (Var6), and participation in training (Var8) suggest that those aware of sustainability principles are more likely to act. The challenges in adopting sustainable fertilization practices (Var9) and the support needed (Var10) show a perfect correlation, reinforcing that financial and informational constraints significantly impact adoption rates.

Table 2. The simple Spearman correlations between the variables concerning the sustainable promotion of plant nutritional status

Issue	Var1	Var2	Var3	Var4	Var5	Var6	Var7	Var8	Var9	Var10
Var1	1.00	-0.16	0.62	0.62	0.57	0.62	0.41	0.65	-0.05	-0.05
Var2	-0.16	1.00	-0.45	-0.45	-0.87	-0.70	-0.91	-0.59	-0.82	-0.82
Var3	0.62	-0.45	1.00	1.00	0.62	0.72	0.66	0.76	0.30	0.30
Var4	0.62	-0.45	1.00	1.00	0.62	0.72	0.66	0.76	0.30	0.30
Var5	0.57	-0.87	0.62	0.62	1.00	0.88	0.92	0.82	0.66	0.66
Var6	0.62	-0.70	0.72	0.72	0.88	1.00	0.88	0.95	0.47	0.47
Var7	0.41	-0.91	0.66	0.66	0.92	0.88	1.00	0.77	0.69	0.69
Var8	0.65	-0.59	0.76	0.76	0.82	0.95	0.77	1.00	0.39	0.39
Var9	-0.05	-0.82	0.30	0.30	0.66	0.47	0.69	0.39	1.00	1.00
Var10	-0.05	-0.82	0.30	0.30	0.66	0.47	0.69	0.39	1.00	1.00

Var1 - Methods used to improve plant nutrition; Var2 - Fertilizers used most often; Var3 - Evaluation of the effectiveness of plant nutrition practices; Var4 - Concerns about the environmental impact of fertilization; Var5 - Measures to minimize the negative impact of fertilization on soil and water; Var6 - Awareness of the benefits of regenerative agriculture for plant nutrition; Var7 - Sources of information about plant nutrition and fertilization; Var8 - Interest in participating in training or workshops on sustainable crop fertilization; Var9 - Challenges faced in adopting sustainable fertilization practices; Var10 - Support needed to adopt more sustainable practices.

The implementation of PCA reveal that the first principal component, accounting for 66.634% of the variance, is associated with practices used for plant nutrition, where fertilizers used most often show a strong positive factor loading of 0.8475, while methods used to improve plant

nutrition and the evaluation of their effectiveness have negative loadings, suggesting that the choice of fertilizers influences perceptions more than the actual methods or perceived effectiveness (Table 3).

Table 3. The principal compenets analysis on variables of the sustainable promotion of plant nutritional status

Eigenvalue	Variance, %	Factor	Item	Factor loading
6.6634	66.634	Practices used for plant nutrition Mean = 2.267 SD = 0.944	Methods used to improve plant nutrition	-0.5557
			Fertilizers used most often	0.8475
			Evaluation of the effectiveness of plant nutrition practices	-0.7935
2.0988	20.988	Sustainability and environmental impact Mean = 2.233 SD = 0.916	Concerns about the environmental impact of fertilization	-0.7935
			Measures to minimize the negative impact of fertilization on soil and water	-0.9479
			Awareness of the benefits of regenerative agriculture for plant nutrition	-0.9259
1.2378	12.378	Perception and access to information Mean = 1.900 SD = 0.481	Sources of information about plant nutrition and fertilization	-0.9469
			Interest in participating in training or workshops on sustainable crop fertilization	-0.8821
			Challenges faced in adopting sustainable fertilization practices	-0.6879
			Support needed to adopt more sustainable practices	-0.6879

The second component, explaining 20.988% of the variance, relates to sustainability and environmental impact, with strong negative loadings for concerns about fertilization's impact, measures to mitigate these effects, and awareness of regenerative agriculture, indicating that higher awareness is linked to increased concern and action. The third component, covering 12.378% of the variance, pertains to perception and access to information, where sources of information, interest in training, and challenges in adopting sustainable practices all have strong negative loadings, suggesting that greater access to knowledge and participation in educational programs are associated with a heightened recognition of challenges and the need for support (Table 3).

CONCLUSIONS

The findings highlight crop rotation as the preferred method for plant nutrition, while the combined use of chemical and organic fertilizers reflects a balanced approach. Despite moderate perceived effectiveness, there is potential for optimization, with sustainability concerns widely acknowledged but not always addressed in practice. Limited awareness of regenerative agriculture underscores the need for educational initiatives. Reliance on fertilizer manufacturers as a primary information source suggests industry influence, while low engagement with scientific research presents opportunities for diversified knowledge access. Strong interest in training contrasts with financial and accessibility barriers, with the high cost of

organic fertilizers being the main obstacle. Financial support, expert collaboration, and improved information dissemination are essential for promoting sustainable fertilization practices.

The correlation analysis reveals that improved plant nutrition methods are linked to higher awareness and perceived effectiveness, while reliance on certain fertilizers is associated with lower engagement in sustainability strategies. The principal component analysis confirms that plant nutrition practices, sustainability concerns, and access to information are the key factors influencing perceptions of carbon sequestration, with financial and technical support playing a crucial role in driving sustainable agricultural transitions.

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