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Exploring the Potential of *Pachyrhizus erosus* in Enhancing Nitrogen Fixation and Soil Fertility Within Regenerative Agricultural Systems: A Pathway to Sustainable Farming

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ABSTRACT

This paper examines the opportunities of *Pachyrhizus erosus* (Jicama) to improve sustainable agriculture with respect to its specialization in fixing nitrogen, permating soils, and controlling pests (IPM). The symbiosis of Jicama with the Brady rhizobium strains is able to fix nitrogen in the atmosphere, which leads to a reduction in the reliance on synthetic fertilizers, regenerative farming systems as well as enhance nutrient cycling. It also has allelopathic effects that inhibit the growth of the weed, and its natural insecticidal elements, such as rotenone, provide a natural substitute to chemical pesticides, and thus, increases organic farming practices. The paper reveals that intercropping Jicama with crops that are intensive in nitrogen like Zea mays (sweet corn) is economically viable and enhances production of crops in particular in tropical and subtropical areas where fertilizer prices are on the increase. In addition, the study highlights the versatility of Jicama not only as a crop to be used in sustainable agriculture but also in the way the crop can be used in agro-industrial purposes, especially in the production of health foods. In this paper, the author urges a wider use of jicama in the smallholder farming systems that can result in cost-effective, environmentally sustainable practices as well as help to accomplish the Sustainable Development Goals (SDGs) such as responsible consumption (SDG 12) and climate action (SDG 13).

Keywords: *Jicama, Nitrogen Fixation, Regenerative Agriculture, Soil Fertility, Intercropping, Sustainable Farming*

INTRODUCTION

Jicama (*Pachyrhizus erosus*) is a tropical leguminous plant in the family Fabaceae, (Wikipedia, 2021) and is generally well-known as with an inwardly crisp and tubular morphology (Kishore, A. et.,al, 2024), eating which runs over different geographic regions, such as the Philippines (singkamas), India (sankalu), and China (fan-ko) Singh, Patel, & Jaiswal, 2021). Despite being a popular source of nutritious dieting, its impact on an extensive agronomic and ecological level has received growing concern over the past years (Huss, C. P., et.al, 2022; Sher, A., Li et.al, 2024). The utilization of jicama as part of sustainable agricultural systems should be looked upon with due seriousness because it is not only a good food crop but also an arbiter of soil vitality, biodiversity and a redressor to dependency on synthetic fertilizers as well (Khangura, R. et.al, 2023; Sher et al. 2024).

Jicama stands out due to its ability in atmospheric nitrogen fixation via a symbiotic association with Brady rhizobium strains thus making an important contribution to it (Jaiswal et al., 2021). Such a kind of biological fixation of nitrogen reduces the use of the synthetic fertilizers and is also consistent with the regenerative goal in agriculture to maintain soil health and promote cycling the nutrients (Singh, Patel, & Jaiswal, 2021). It is synergistic with intercropping jicama, especially when it is used with nitrogen-intensive crops such as Zea mays (sweet corn): the nitrogen used to improve the growth of companion crops creates synergistic effects and improves the total yield, which later allows it to make efficient use of the resource base (including light, water and nutrient) (Elona et al., 2023). These types of intercropping are characteristically economically viable more particularly in tropical subtropical environments where nitrogenous fertilizers tend to be overly expensive and as such, farmers will be able to save money whilst maximizing their profits as a result of the adoption of sustainable methods.

Another property of Jicama (*Pachyrhizus\erosus*) is its central role in the Integrated Pest Management (IPM), such as contributes to the suppression of the growth of weeds by allelopathic mechanisms. The extracts prepared using aqueous solutions of different parts of the plant, such as foliage, stems, and tuberous root, have been shown to prevent the proliferation of the weed, and empirical literature demonstrates a 92 percent decrease in the germination of the weed of the type of plants, known as Bidens pilosa (Common Beggarticks), and a 91 percent reduction in the dry weight of the weed seedlings (Barbosa et al., 2018).

Besides, Jicama contains rotenone in its roots and stems, which is a natural insecticidal substance and is effective in eliminating the population of pests, which makes the plant more environment-friendly compared to synthetic chemical substances (Barbosa et al., 2018; Li et al., 2020). These natural control functions which pests have made Jicama an effective part of organic production, reducing the reliance on dangerous pesticides and providing sustainable agriculture practices which bring benefits both to the health of crops and to the sustainability of the environment (Shoaib et al., 2016; Praveen and Jayabalan, 2020).

Increasing fertilizer prices present a significant challenge to the sustainability of agriculture particularly to the smallholder farmers who are experiencing unreliable price elasticity and rising prices of inputs despite the rising attempts made by the Fertilizer Industry Authority to control the prices. This situation raises the importance of the need to have new ways of agricultural practices that will not only reduce financial costs but also promote environmental sustainability. One possible solution is the intercropping of Jicama (*Pachyrhizus erosus*) with other crops, which will help to increase land and nutrient-use efficiency, promote the cycling of the nutrients, and strengthen agro-biodiversity.

With Jicama farming offers great benefits to smallholder farmers, especially in areas where other farming inputs are unaffordable. An example of this benefit is the intercropping system (with jicama and sweet corn in Zamboanga Sibugay), which has shown to increase yields while reducing the need for synthetic fertilizers and pesticides (Elona et al, 2023; Li et al, 2019; Agrawal et al, 2023). The existence of such advantages, such as the efficient use of light, water, and nutrients, make intercropping systems based on jicama very productive, even when limited in acreage conditions (Kishore et al., 2024; Velasco and Ramirez, 2022). These impacts help limit the environmental impacts and provide cost-effective solutions for farmers in line with the Sustainable Development Goals (SDGs) of responsible consumption and production (SDG 12) and climate action (SDG 13) (Velasco & Ramirez, 2022; Bhuvaneshwar & Devraj, 2021).

The versatility of jicama, which includes both the nutritional and agronomic features, places it as a central scope within sustainable agriculture. Its nitrogen fixation activities boost the health of the soils, while its natural pestical characteristics can be beneficial to deal with integrated pest management and encourage organic and low chemical farming (Shoaib et al., 2016; Velasco & Ramirez, 2022). Furthermore, the prebiotic and antioxidant properties of jicama have helped provide great value in the food and nutraceutical industries (Praveen & Jayabalan, 2020; Bhanja et al., 2023). Recent studies point out the growing alternatives of jicama in agriculture and food production, a promising path toward environmental protection, food security and sustainable farming, which are key objectives in the SDGs (Velasco & Ramirez, 2022; Jean et al., 2017). Lastly, jicama has great potential for agro-industrial application, especially in the manufacture of health benefits foods, showing its relevance in the current industrial process (Khangura et al., 2023; Li et al., 2020).

METHODOLOGY

This paper takes a systematic review approach to examine jicama (*Pachyrhizus erosus*) particularly its capacity to fix nitrogen and the role it has as a herbicide / pesticide on sustainable farming. We sought pertinent researches in reputable academic libraries like Brisbane Google scholar, Pubmed, Web of Science, and ScienceDirect. Words such as Pachyrhizus erosus, nitrogen fixation, herbicidal properties of jicama, and integrated pest management were used. Articles that were published after 1990 were only selected to concentrate on the latest study.

The research selected were meeting certain criteria. They were required to concentrate on the work of jicama in the ecology (the fixation of nitrogen with Bradyrhizobium), or of going under water to fix its herbicide and pesticides. The research also needed to examine the application of jicama in the practice of sustainable agriculture and regenerative agriculture. Papers, which merely mentioned the price of jicama, or parts of the economy, but nothing about the farming or ecological role, were omitted.

Following the selection of studies, we were able to collect important information about nitrogen fixation, pest control properties (such as the existence of rotenone), and the impact of jicama on soil health and agricultural systems. These findings were combined into themes, namely nitrogen fixation, potential of herbicides/pesticides, and sustainability. Then we compared the literature with a view to identifying primary trends and findings, including the extent to which jicama could substitute synthetic fertilizers and pesticides.

To ensure that the information used was credible, we considered the quality of each study in terms of methods and gave more preference to the ones that had clear experimental designs, good sample size and quality statistics. Field experiments and randomized controlled trials were considered to be stronger studies. We have just considered English-language papers, and this may have omitted valuable research in other languages.

We synthesized all the results to emphasize the agricultural advantages of jicama, its ability to fix nitrogen, its application in questionable plant control, and its potential to be a regenerative crop. This overview would have a better perspective of how jicama could serve sustainable farming and offer eco-friendly solutions.

RESULTS AND DISCUSSIONS

The examination of the current scientific literature related to *Pachyrhizus erosus* (jicama), it has been discovered that there are strong elements associated with this plant with regard to its physiology, especially in relation to nitrogen fixation processes, herbicidal and pesticides, as well as crops that can be planted with them in a sustainable and regenerative system of farming. One of the important findings is jicama's fixation of nitrogen via its symbiosis with the bacterium *Bradyrhizobium* which inhabits its roots. This relationship is important in improving the soil fertility, especially in soil which is low in nitrogen and constitute a natural alternative fertilizer instead of using artificial fertilizers. By enriching the soil with its N fixing capabilities, jicama is an ideal candidate in regenerative farming practices that strive to make better use of the soil and reduce the use of chemicals in their production. Studies have shown that jicama intercropping with nitrogen-demanding crops like sweet corn enhances crops with increased growth yields by increasing the availability of nutrients in soil to further support the role of jicama in enhancing soil fertility in diversified agroecological systems (Bhanja et al., 2023).

In addition to its nitrogen fixation ability, jicama contains the once insecticide and herbicide responsible, naturally occurring compound known as rotenone in its roots and stems. This makes jicama a useful tool in integrated pest management (IPM) systems providing a natural and eco-friendly alternative to chemical pesticides/Herbicides. By using jicamas natural pesticide properties, we can greatly reduce our Synthetic Chemical dependency which is especially an important factor in today's trend towards organic and sustainable farming practices. The presence of rotenone is a natural solution to pest control and could be an innovative move towards low-input farming systems, where the use of chemicals is kept as low as possible (Cantwell et al., 1992).

Jicama also has proven to be a versatile companion crop of sweet corn in intercropping systems. Research shows that when jicama is intercropped with sweet corn, it greatly improves growth of corn especially for plant height, stalk circumference and ear weight. This is a mutual benefit as the nitrogen fixation by jicama is responsible for improving the availability of soil nutrients for the better growth of sweet corn. The quincunx planting method, where the jicama is planted among every row of sweet corn, is the optimal form of use of light, water and nutrients, thus optimizing the productivity of the crop. This technique not only optimises the use of resources but also cuts cost inputs which again demonstrates the worth of jicama when used in regenerative farming (Elona et al. ,2023).

The economic benefits of intercropping jicama with other crops are high, especially where the costs of input for synthetic fertilizers and pesticides are high. In some areas such as Zamboanga Sibugay it has been found that intercropping jicama plants with sweet corn can help reduce these expenses and yields more crops. By taking advantage of the nitrogen-fixing capabilities of jicama, farmers are able to curb the reliance on man-made fertilizers, resulting in lower costs and higher level of profitability. Furthermore, jicama as green manure and fodder adds to soil fertility and structure and thus can be regarded as a valuable tool for soil conservation and water management. Its deep root system also helps to prevent soil erosion, which is especially important in drought-prone areas (Bhanja et al., 2023).

Although the benefits of jicama with regard to regenerative agriculture are notable, there are still gaps in the literature that need to be addressed. Large scale trials and economic assessments are required to assess long term effectiveness of jicama in different types of farming systems, especially for commercial farming. More research is also needed to fully understand the nitrogen fixation mechanism in jicama and how it works with other crops in systems with multiple crops. Studies which focus on jicamas economic impact and scalability in low input farming system are imperative to determine its feasibility as a mainstream crop

Concluding, *Pachyrhizus erosus* is an excellent crop for sustainable and regenerative farming systems because of its nitrogen fixing properties, pesticides, and nutritive properties provided by inulin. Its capacity to enhance soil health, lower the requirement for synthetic fertilizers and pesticides, and boost the productivity of harvests, make it a crucial part of regenerative farming. Intercropping of jicama with other crops, as the green manure, and minimizing the use of chemicals only add an additional value to jicama in these farming systems. In the future, efforts should be directed towards testing its scale up, understanding the nitrogen fixing process and its economics for different applications to further its role in low-input sustainable agriculture all over the world.

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