JOURNAL OF THE Selva Andina Biosphere
Official Journal of the Selva Andina Research Society.

Communication Technique

ISSN 2308-3867 (print edition)
JSAB
ISSN 2308-3859 (online edition)

Biointensive and traditional production systems on agronomic parameters of vegetables

Sistemas de producción biointensiva y tradicional sobre parámetros agronómicos de hortalizas

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Article Data

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Keywords:

Biointensive,
agricultural system,
Bolivian Altiplano,
Microorganisms.

J. Selva Andina Biosph. **2022; 10(1):57-65.**

Article ID: 107/JSAB/2021

Article history.

Recibido julio, 2021.
Devuelto octubre, 2021.
Aceptado febrero, 2022.
Disponible en línea, mayo 2022.

Edited by: Selva Andina Research Society

Palabras clave:

Biointensivo,
sistema agrícola,
altiplano boliviano,
microorganismos.

Abstract

The Altiplano of Bolivia faces droughts and frequent frosts due to climate change, which affect yields and productivity of vegetables. Pro Rural, together with the Technical University of Oruro, has developed and implemented Biointensive Agroecological Family Units (UFABs) as an alternative to family agricultural production in the Altiplano, characterized by the efficient use of water, improving soil properties through localized fertilization and the substitution of agrochemicals for agro ecological inputs. The objective of this research was to determine two agricultural production systems on agronomic parameters of six vegetables. An experimental area was established in a factorial arrangement arranged in a randomized complete block design with six treatments (vegetable species) and two production systems (biointensive and traditional system), drip irrigation in the biointensive system and flooding in the traditional system. According to the results obtained on agronomic parameters, there is a statistical difference in yield and agronomic variables (plant weight, root length, and plant height) showing a superiority in the biointensive system, similar results are seen in leafy vegetables, the volume of water consumed shows that there is greater efficiency in the use of drip irrigation system with 90%, the amount of soil microorganisms is more than 50% in the biointensive system, similar results are seen in the chemical analysis of the soil.

Resumen

El altiplano de Bolivia afronta sequias, heladas frecuentes debido al cambio climático, que afecta los rendimientos y la productividad de las hortalizas, Pro Rural conjuntamente con la Universidad Técnica de Oruro, ha desarrollado e implementado Unidades Familiares Agroecológicas Biointensivas (UFABs) como una alternativa a la producción agrícola familiar en el altiplano, caracterizado por el uso eficiente del agua, mejorando las propiedades del suelo mediante la fertilización localizada y la sustitución de agro-químicos por insumos agroecológicos. El objetivo de esta investigación fue determinar dos sistemas producción agrícola sobre parámetros agronómicos de seis hortalizas. Se estableció un área experimental en arreglo factorial dispuestas en un diseño bloques completos al azar con seis tratamientos (especies de hortalizas) y dos sistemas de producción (bio intensivo y sistema tradicional), riego por goteo sistema biointensivo e inundación en el sistema tradicional. Según los resultados obtenidos sobre parámetros agronómicos se aprecia que existe diferencia estadística en rendimiento y variables agronómicas (peso planta, longitud raíz, y altura planta) apreciándose una superioridad en el sistema biointensivo, similares resultados se aprecia en las hortalizas de hoja, el volumen de agua consumido se aprecia que existe mayor eficiencia en el uso del sistema de riego por goteo con un 90 %, la cantidad de microorganismos del suelo es más de un 50 % es sistema biointensivo, resultados similares se aprecia en los análisis químicos del suelo.

Introduction

In Bolivia there are about 872000 agricultural production units (APU), 92 % are family farmers, 7 % are medium-sized farmers, 1 % are large farmers[1], most of which are located in the highlands, characterized by low incomes, greater vulnerability and low productivity levels[2].

Agriculture in the Altiplano is at high risk, with adverse climatic events such as drought, frost, irregular rainfall, hail, strong winds, low availability of water for irrigation, loss of soil fertility and threats to agricultural productivity[3], influenced by the climatic variability of the area, farmers' perception of climate change (CC), indicate that the loss of their production is due to drought (83.6 %), frost (7.4 %), wind (6 %) and hail (1.5 %)[4].

A traditional system (TS) of agricultural production is characterized by the absence of capital, excessively fragmented land, scarce technology, which makes it impossible to expand the cultivable area and technology, therefore, the Altiplano has the lowest productivity indexes compared to other sectors of the country's economy[5], in contrast, as an alternative to improve the agro-ecological method, biointensive agriculture (BIA), based on the use and incorporation of organic matter (OM), as well as optimization of the use of water and soil[6].

BIA is defined as the intensification of agricultural productivity through biological means on a minimum area of land, improving the soil at the same time, combining principles of biodynamic agriculture[7], based on agro ecological principles, indigenous technology, knowledge, experience, needs and an analysis of the negative impact on conventional agriculture[8]. BIA decreases dependence on seasonal rainfall, takes advantage of small available land, improves soil quality by applying high level fertilization, the use of drip irrigation and the rational use of irrigation water[9], diversified production, with high yields[10].

The importance of introducing new production systems such as BIA for vegetables lies in increasing yields 6 times more in small extensions[3]. The vegetable yield in the Altiplano is below national production, characterized by inadequate soil management and little agricultural technology, which results in low yields.

In this research, we evaluated the effect of the two biointensive agricultural production systems compared to the TS on agronomic parameters of vegetables, soil fertility, amount of fungi and water consumption.

Materials and methods

The study was conducted at the Condoriri Agricultural Experimental Center (central highlands) of the Technical University of Oruro[11], together with PRO-RURAL, an institution whose objective is to contribute to the economic, social and environmentally sustainable development of vulnerable rural men, women and youth[3] in the highlands of Bolivia. The study was conducted during the 2017 to 2018 agricultural seasons, the soil has a loamy texture, moderate OM, with low nitrogen content, phosphorus, potassium in moderate concentrations, average annual relative humidity 49 %, it is characterized by an annual maximum temperature of 27.2º C, a minimum of -15º C, an average of 9.5º C, frost frequency of 162 days and an annual precipitation of 461. 2 mm[12] Two experimental plots of 425 m^2 were established, distributed in 12 treatments, 2 production systems (biointensive, traditional) and six vegetables (turnip, radish, beet, lettuce, carrot, onion), the six species were sown per production system and randomly distributed in each repetition, The plots were arranged from north to south with a spacing of 2 m between them to control factors that could influence the treatments, distributed in a factorial arrangement arranged in completely randomized blocks (CRB)[13]. In both systems, 5 kg m^{-2} of manure (cattle manure) was incorporated before pre-soil preparation. In addition, in the biointensive system (BIS), also known as bio-intensive agriculture, 35 cm high beds were prepared and a drip irrigation system was established. The BIS, a 60 cm double-digging technique[14].

The agronomic parameters evaluated were plant weight (PW) (g), root length (RL) (cm), plant height (PH) (cm), upper and lower bulb diameter (ULBD) (cm), plant height (AH) (cm) and yield (kg m^{-2})[15], for leafy vegetables (PW) (g), number of leaves (NL) (units), RL (g), AH (cm) and yield (kg m^{-2})[16].

Likewise, the volume of irrigation water was estimated in 2 systems by drip (BIS) and flooding[9] (TS), the influence of agricultural production on soil fertility[5] was determined in both systems, the quantity of fungi by the method of soil dilution analysis in plates which is the weight of 10 g of soil and then introduced into 500 mL Erlenmeyer flasks, to this was added 90 mL of sterile distilled water and shaken for 10 min (standard solution 1:10), from this solution 1 mL was taken with the pipette and mixed with 9 mL of sterile distilled water in a test tube suspended to solution 1:100, this step was repeated until the desired dilution was obtained[17], OM (calcination method), chemical properties Ca, Mg, Na, K, P, (Atomic Absorption method), total N (Kjeldahl method)[18], soil samples were taken by treatment and homogenized, the microbiological analysis was carried out in the laboratories of the Department of Agriculture of FCAN[19] and the chemical analysis in the IBTEN laboratory.

Results

Agronomic parameters. In Table 1, turnip cultivation in BIS obtained the highest PW with 758.7 g, higher than TS with 118.9 g, as well as in RL and AH. The yield in the BIS was 18 kg m^{-2} higher than the traditional with 4.5 kg m^{-2}. In radish the PW was 65.4 g BIS, a higher yield with 3 kg m^{-2} superior to the traditional with only 2.1 kg m^{-2}. In beet, the BIS presented a higher weight with 118.9 g, higher than the traditional one with 106.0 g, similarly, the yield was higher with 4 g m^{-2} and 2.7 g m^{-2}. In lettuce, greater weight and NL were observed in the BIS compared to the traditional with 633.3 and 333.9 g, 15 and 13 leaves, respectively. In the carrot crop, the PP was 69 g in the intensive system, higher than in the traditional system with only 29 g. In the onion crop, the PW was higher with 157 g compared to the traditional with 63 g, in the same way, the bulb diameter and yield reported superiority in the biointensive production.

Water use. The volume of water applied in the entire vegetative cycle of the crop in the BIS was 63.9 m^3 with drip irrigation, lower than the flood irrigation system of 282.2 m^3, regarding the application efficiency the drip irrigation system reports 90 % efficiency, flood irrigation reports an efficiency of 47 %, re-porting a net volume of water applied of 57.5 m^3 by drip and 132.65 m^3 by flood.

Microorganisms. The amount of fungi in the two systems (Figure 1), there is a higher amount of fungi in the biointensive system compared to the ST. The BIS reported an average of $6.5x10^4$ CFU g/soil, higher than the traditional system, which reported an average of $1.5x10^4$ CFU g/soil.

Organic matter. The biointensive plot pre-sents 1 % of OM, above the traditional one (Figure 2).

Chemical properties. Calcium in both systems is found in high concentrations. Magnesium in the biointensive plot is high and moderate in the traditional plot, sodium in both cases is very low, potassium reports high contents, total nitrogen high and - assimilable phosphorus very high in both systems.

Table 1 Agronomic parameters by effect of biointensive and traditional systems in vegetables

Vegetable/Variable	Production system	
	Biointensive	Traditional
Turnip		
Plant weight g	758.7 a*	118.9 b
Root length cm	11.1 a	7.01 b
Plant height cm	35.3 a	18.4 b
Yield kg m^{-2}	18.0 a	4.5 b
Radish		
Plant weight g	65.4 a	61.7 a
Root length cm	7.7 a	6.8 a
Plant height cm	22.4 a	21.4 b
Yield kg m^{-2}	3.0 a	2.1 b
Beets		
Plant weight g	118.9 a	106.0 b
Root length cm	6.4 a	5.6 b
Plant height cm	31.5 a	30.7 b
Yield kg m^{-2}	4.0 a	2.7 b
Lettuce		
Plant weight g	633.3 a	333.9 b
Number of leaves	15.0 a	13.0 b
Root length cm	18.8 a	12.8 b
Plant height cm	12.0 a	8.8 b
Yield kg m^{-2}	11.3 a	10.2 b
Carrot		
Plant weight g	69.9 a	28 b
Upper diameter cm	3.4 a	2.4 a
Lower diameter cm	1.2 a	1.2 a
Root length cm	9.3 a	7.9 b
Yield kg m^{-2}	1 a	0.6 a
Onion		
Plant weight g	157.9 a	63.1 a
Bulb diameter cm	6.4 a	4.3 a
Bulb height cm	6.4 a	6.2 a
Root length cm	4.3 a	4.0 a
Yield kg m^{-2}	2.5 a	1.3 b

*Letras similares son estadísticamente similares.

Table 2 Water use in biointensive and traditional production system

Parameter	Drip Irrigation	Flood irrigation
Unit flow rate (L/h)	1.3	
Flow rate at the head of the plot in (L s^{-1})		3.2
N° of drippers (m^2)	6	
Irrigated area (m^2)	425	425
Irrigation time hours	1.8	3.5
No. of irrigation agricultural cycle	11	7
Flow rate applied to the plot (L/h)	3228	11520
Volume of water applied per irrigation (m^3/par.)	5.81	40.32
Volume of water applied throughout the entire C.V. (m^3/par.)	63.92	282.24
Application efficiency (%)	90	47
Net volume of water applied in the C.V. (m^2/par.)	57.528	132.6528

Figure 1 Number of fungi in biointensive and traditional biointensive and traditional production systems

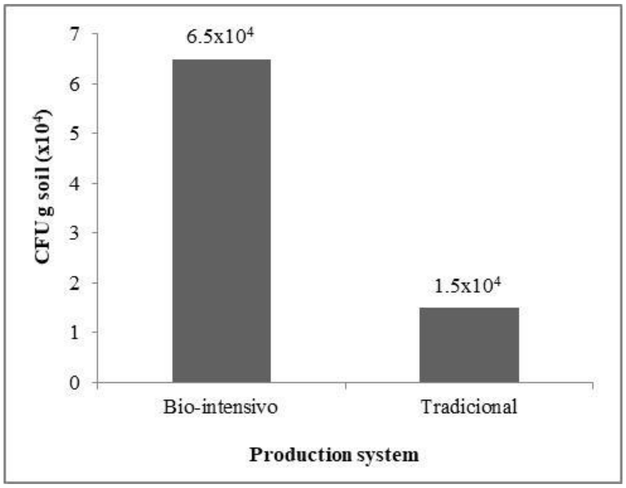

Figure 2 Organic matter in biointensive and traditional biointensive and traditional management systems

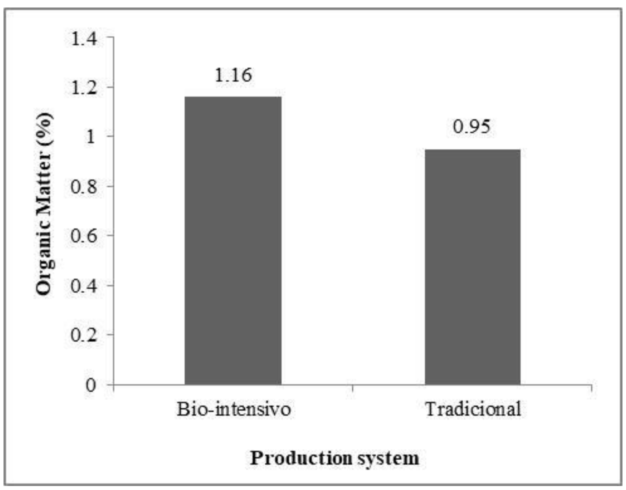

Table 3 Chemical properties in the two production systems

Parameter	Bio-intensivo	Traditional
Calcium	13.61	11.48
	High	High
Magnesium	5.42	3.43
	High	Moderate
Sodium	0.85	0.81
	Very Low	Very Low
Potassium	2.88	2.75
	High	High
Total nitrogen	0.21	0.27
	High	High
Assimilable phosphorus	50.55	102.21
	Very High	Very High

Discussion

This analysis shows that even under adverse conditions, with the implementation of agroecological[20] and biointensive technologies, the yield was higher in relation to a vegetable production TS, this could be due to the higher fertilization in the plots with 5 kg m^{-2}/[21] that not only provides nutrients, but also reactivates the microbial activity of the soil[22], it has been established that soils with high OM content tend to contain more microorganisms with complex mandates[23]. A synergy, symbiosis is generated between microorganisms and crops[24], this is indicated by the microbiological analysis obtained in the BIS with an average of $6.5x10^4$ CFU of fungi; it is important to mention that bacteria and actinomycetes also act in the soil as OM decomposers[23], in contrast to the TS $1.5x10^4$ CFU[25], however, in both soils the same amount of fertilizer has been incorporated[26]. The difference between the results could be due to the fact that there is a greater volume of soil or arable layer due to the use of the high 60 cm plantain bed technique, in comparison with the TS, which has 30 cm[27], the crops develop a greater number of roots and interact better with the microorganisms[28]. On the other hand, drip irrigation generates little compaction, as opposed to flood irrigation[29].

After evaluating the two production systems on agronomic parameters, soil fertility and water consumption, it can be observed that there is a statistical difference, reporting high yields in most of the orchards with the BIS. It has been determined that yields increase by an average of 30 % in a conventional production in the first year[30]. Yields compared with the average for vegetables in Bolivia[31], the results show to be high (Table 4), which constitutes an alternative to increase them, especially in family agriculture.

In relation to the other chemical parameters[32], the differences are minimal, this could be due to the characteristics and nature of the soils of the Bolivian Altiplano, the incorporation of fertilizer would generate better conditions for the development of crops and microorganisms[33], under the logic that the soil has recovered and becomes a "Living Soil".
According to the results obtained from the evaluation of two production systems, on agronomic parameters, soil fertility and water consumption, it can be observed that there is a statistical difference in yield and agronomic variables in most of the vegetables, showing a superiority with the BIS.

The BSI, in comparison with the traditional one, influenced the quantity of soil microorganisms by more than 50 %. For the other chemical components analyzed, a slight superiority is observed in the bio-intensive system in the first year of implementation.
The volume of water consumed shows that there is greater efficiency in the use of the drip irrigation system with 90 % efficiency, the flooding system has an efficiency of 47 %. The APU is adapted to the gradual reduction of the water supply for irrigation that currently exists in the Altiplano, making it a mechanism for adapting to climate change.

Table 4 Comparative yields in Bolivia of the biointensive and traditional systems

Cultivation	Average yield Bolivia (kg m^{-2}) INE	Biointensive (kg m^{-2})	Traditional (kg m^{-2})
Turnip	0.74	18.0 a	4.5 b
Radish	0.48	3.0 a	2.1 b
Beet	0.66	4.0 a	2.7 b
Lettuce	0.63	11.3 a	10.2 b
Carrot	1.00	1.0 a	0.6 a
Onion	1.40	2.5 a	1.3 b

Modified data from INE[30]

Biointensive APU´s are an alternative for family farming in the highlands of Bolivia, they are adapted to the low level of land tenure of small farmers, improve food productivity to ensure food security for farmers and take advantage of livestock manure, water, soil, but with agroecological methods that contribute to the sustainability of agro-ecosystems and local livelihood systems.

Source of financing

This study was carried out thanks to the logistical support of PRORURAL of the IMSA Project in agreement with the Technical University of Oruro.

Conflicts of interest

This research was carried out in the Project "Effect of the type of bio-intensive and traditional production system on agronomic parameters of vegetables" headed by the Faculty of Agricultural and Natural Sciences of the Technical University of Oruro and there is no conflict of interest.

Acknowledgments

This study was carried out thanks to the logistical support of PRORURAL of the IMSA Project in agreement with the Technical University of Oruro.

Ethical considerations

The research was approved by the Research Department of the Universidad Technical de Oruro and followed the regulations established for this process.

Research limitations

The authors point out that there were no limitations in the present research work.

Authors' contribution

Edwin Marcelo Gonzales-Torrico, experiment planning, statistical analysis and systematization and interpretation of information. *Fernando Pacasa-Quisbert,* data collection and systematization and interpretation of information. *Juvenal Hurtado-Barreto,* systematization and interpretation of the information. Revision of the document.

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