Verification of alternatives for sustainable onion production (*Allium cepa* L.) in Cucaita, Boyaca

Verificación de alternativas para la sostenibilidad de la producción de cebolla (*Allium cepa* L.) en Cucaita, Boyacá

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ABSTRACT

In Cucaita, onion production represents the basis of the economy and is concentrated in the valley but as yield declines due to deterioration of the soil, cultivation is shifting to the slopes, where unsustainability is more prominent. The aim of this study was to verify the potential of three alternatives for sustainable farming, using a split plot design on two farms. The alternatives were: 1) bocashi chicken manure, super broth four, fertilizer (BCmSB4F), 2) bocashi cow manure, rhizosphere broth, super broth four, fertilizer (BCmRBSB4F), 3) green manure, rhizosphere broth, super broth four, fertilizer (GmRBSB4F) and 4) regional control (RC). This study determined disease incidence, plant height, stem and bulb diameter, healthy and diseased bulb weight and yield. The results indicated that regardless of the alternative, the agro-ecological conditions of the farm are critical to plant health and consequently to crop production. In El Arenal, where disease incidence was lower, the highest values for healthy bulb weight, bulb diameter and yield were revealed. The alternatives only differed in disease incidence at 30 and 45 days after transplant, with the lowest percentages corresponding to the green manure alternative. For revenue, the three alternatives were favorable, especially the BCmRBSB4F alternative which exceeded the RC. The results show that the alternatives GmRBSB4F and BCmRBSB4F have the most potential and are the most viable for sustainable onion production in Cucaita, Boyaca.

Key words: sustainable alternatives, bocashi, green fertilizer, rhizosphere broth, super broth four.

RESUMEN

En Cucaita, la producción de cebolla que representa la base de la economía se concentra en el valle pero a medida que los rendimientos disminuyen debido al deterioro de los suelos el cultivo se desplaza a las laderas, donde el riesgo de insostenibilidad es mayor. El objetivo de la presente investigación fue verificar el potencial de tres alternativas para la sostenibilidad del cultivo, utilizando el diseño de parcelas divididas en dos fincas. Las alternativas fueron: 1) bocashi gallinaza, caldo súper cuatro, fertilizante (BgCSF), 2) bocashi bovinaza, caldo rizósfera, caldo súper cuatro, fertilizante (BbCRCSF), 3) abonos verdes, caldo rizósfera, caldo súper cuatro, fertilizante (AvCRCSF) y 4) testigo regional (TR). Se determino incidencia de enfermedades, altura de planta, diámetro de tallo y bulbo, peso bulbos sanos y enfermos y rendimiento. Los resultados indicaron que independientemente de la alternativa las condiciones agroecológicas de la finca son decisivas para la sanidad fitosanitaria y en consecuencia para la producción del cultivo. En la finca El Arenal, donde la incidencia de enfermedades fue menor, se produjo el mayor peso de bulbos sanos, diámetro del bulbo y rendimiento. Entre alternativas se presentaron diferencias únicamente en incidencia de enfermedades a los 30 y 45 días del trasplante, correspondiendo los menores porcentajes a la alternativa de los abonos verdes. En rentabilidad las tres alternativas resultaron favorables, especialmente la alternativa BbCRCS4F que supero al TR. Se concluye que las alternativas BbCRCS4F y AvCRCS4F son las de mayor potencial y las más viables para la producción sostenible de cebolla en Cucaita, Boyacá.

Palabras clave: alternativas sostenibles, bocashi, abonos verdes, caldo rizósfera, caldo súper cuatro.

Introduction

Onion cultivation has represented the basis of the economy for several years in Cucaita (Méndez, 2007). Currently, production is concentrated as monoculture in the valley, but as yields decline due to the deterioration of the soil, cultivation is gradually moving to the hillside. Monoculture inevitably leads to degradation because it facilitates erosion and loss of organic matter (Troeh *et al*., 1980; Proyecto Checua, 2000; Gómez, 2000).

Local farmers have changed the practices of their ancestors by importing technology, which instead of promoting synergy within the agroecosystems (Altieri, 1996), destroys

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the ecological balance through intensive use of external resources (Viteri, 2002). Accordingly, the cultivation is based on an unsustainable platform.

The Cucaita scenario, similar to that of other regions that have adopted the model of the Green Revolution, forces researchers to continue the search for alternatives that actually lead to the recovery of resources and reorientation of agricultural development in a manner that positively responds to the basic needs and possible advancement of the communities (Altieri, 1996).

Recent research has found that bocashi combined with rhizosphere broth and super broth four has beneficial effects on the biological potential and soil nutrient content (Méndez and Viteri, 2007) and in cold climates, certain associations of green manure represent a viable source of organic matter (Viteri and Méndez, 2003; Viteri and Velandia, 2006; Viteri *et al*., 2008a); therefore, the objective of this research was to verify the potential of these alternatives for sustainable cultivation under the agro-ecological conditions of Cucaita.

The alternatives, which basically focus on the recovery of the productive capacity of soils and the decrease in the use of agrochemicals, were selected in conjunction with the producers, through participatory workshops conducted to share the results of two research projects carried out by the group Manejo Biológico de Cultivos at the Escuela de Ingeniería Agronómica at the Universidad Pedagógica y Tecnológica de Colombia (Tunja, Colombia), during the years 2002 to 2005, financed by Pronatta, Colciencias, Ocensa and the municipalities of Tibasosa and Cucaita.

Materials and methods

The study was conducted on the farms Luvita and El Arenal in Cucaita (05°32'45" N, 73°27'26" W), altitude 2,650 m, average temperature 14.2°C and annual rainfall 760 mm.

The verified alternatives were: 1) Bocashi-chicken manure, super broth four and fertilizer (BCmSB4F), 2) Bocashi-cow manure, rhizosphere broth, super broth four and fertilizer (BCmRBSB4F), 3) green manure, rhizosphere broth, super broth four and fertilizer (GmRBSB4F) and 4) regional control (RC). We used a split plot design with two replications (Gómez and Gómez, 1984). The main plot was represented by the farm and the subplot by the sustainability alternative. The experimental unit area was 75 m^2.

On each farm, in the lot assigned by the farmer, the soil was prepared with two ploughings and one compaction. Following preparation, a representative sample was taken for soil physicochemical analysis.

In the field, the soil was classified as Dystrustept (IGAC, 2005), the physicochemical characteristics are shown in Tab. 1. The layout was made according to the experimental design and in the plots corresponding to the GmRBSB4F alternative, green manure was spread. The green manure

TABLE 1. Physico-chemical properties of the soil in Cucaita farm, Boyaca.

Determination	Luvita		El Arenal	
	Result	Critical level	Result	Critical level
Texture	Clay Loam	-	Clay Loam	-
pH	5.4	Highly acidic	6.5	Slightly acidic
Organic matter (%)	1.7	Low	1.6	Low
P (mg kg^{-1})	12.5	Low	114	High
Al (cmol kg^{-1})	0.2	Low	-	-
Ca (cmol kg^{-1})	11.5	High	9.4	High
Mg (cmol+ kg^{-1})	2.5	Medium	2.0	Medium
K (cmol+ kg^{-1})	0.4	Medium	0.9	High
Na (cmol+ kg^{-1})	0.3	Normal	0.3	Normal
CICE (cmol+ kg^{-1})	14.9	Medium	12.6	Medium
S (mg kg^{-1})	36.2	High	16.1	High
Fe (mg kg^{-1})	122	Medium	28.5	Low
Mn (mg kg^{-1})	4.3	Low	3.2	Low
Cu (mg kg^{-1})	1.7	Low	0.9	Low
Zn (mg kg^{-1})	6.6	High	2.8	Low
B (mg kg^{-1})	0.3	Low	0.2	Low
Electrical conductivity (ds m^{-1})	2.0	Normal	2.0	Normal

Source: Soil Testing Laboratory, UPTC, Tunja (Castro and Gomez, 2010).

used was the common vetch (*Vicia sativa*) with common oats (*Avena sativa*) and radish (*Raphanus sativus*) with a density of 30, 33 and 6 kg ha^{-1}, corresponding to 33.33% of the recommended seeding rate for each species in monoculture, respectively (Proyecto Checua, 2000). The green manure was broadcasted, the same as triple fertilizer 15, with an application rate of 150 kg ha^{-1}. After two months, the biomass produced in each plot was quantified, then cut with a scythe and incorporated into the soil with a rake. For quantification, an area of 1 m^2 was selected in a plot representative of growth, all plants were cut at ground level, including weeds, and fresh weight was measured. For dry weight, a sample was removed from each plant species and subjected to a temperature of 80°C for 24 h. Two weeks after incorporation of the green manure, the onion seed was sowed on each farm, using 500 g of the 'Yellow Granex'. To prevent disease in the nursery, two applications of *Trichoderma harzianum* (Tricho-D®) were used following the label recommendations.

Along with planting, bocashi and rhizosphere broth and super broth four preparation began on each farm, according to the procedure described by Méndez and Viteri (2007). These same authors reported on the chemical and microbiological composition of each of these bio-products, the data have been corroborated in other studies (Viteri *et al*., 2005; Viteri *et al*., 2008b). The reports highlight the great variability of nutrients and beneficial microorganisms that exist in each of the bio-products, which support sustainable farming.

At two weeks after incorporation of the green manure, onions were transplanted in the lot. Following the methodology used previously by Méndez and Viteri (2007), bocashi was broadcasted (6 t ha^{-1}) before transplantation, super broth four 5% at 20, 40 and 60 d and rhizosphere broth 10% at 27, 47 and 67 days after transplant (dat), as supplemental fertilization. In the GmRBSB4F alternative, not including the roots, the amount of organic matter incorporated by green manure was 2.4 and 3.3 t ha^{-1} in Luvita and El Arenal, respectively. The amount of fertilizer applied in the three alternatives was 317 t ha^{-1}, equivalent to a third of the amount generally used by the farmer. The control received a total fertilizer dose of 950 t ha^{-1}.

The weeds were controlled in the crops with the herbicide oxifluorden following the label recommendations. Irrigation supplemented rainfall when necessary. Phytosanitary control was performed preventively with liquefied applications of fern (*Pteridium aquilinum*) 5%, alternated weekly, with cape gooseberry (*Physalis peruviana*) 2% (Viteri *et al*., 2005). Additionally, after 2 months, every 8 d, a bordeaux mixture from the Saferâ company was applied.

During onion growth, disease incidence, plant height and stem diameter were determined. Disease incidence was determined at 30, 45, 60, 75, 90 and 105 dat, counting the number of plants in an area of 1 m^2 that had symptoms of any illness. Plant height and stem diameter were measured at 60, 75, 90, 105 and 120 dat. At harvest, weight for healthy and diseased bulbs, bulb diameter and yield were quantified. The data for each variable were subjected to analysis of variance and in dependence of the significance to the Duncan test, using the statistical program SPSS (IBM®-SPSS 11.5).

Finally, based on production costs and the value of the product in the market at harvest time, we calculated the cost of each alternative.

Results and discussion

Incidence of diseases

The data in Tab. 2 indicate that the differences between farms in incidence of diseases were significant at the end of the growing season, with the lowest percentages at El Arenal. The alternatives had significant differences between the beginning of the growing season, with the green manure (GmRBSB4F) alternative excelling, equaling the regional control. At the end of the growing season, the alternatives did not differ from the control, with control having 100% agrochemical phytosanitation. Similar results have been reported by Méndez and Viteri (2007).

The disease incidence was lowest in the green manure alternative, very close to that observed in the regional control, including in the final stage of the crop (Tab. 2, Fig. 1). The lower incidence of pathogens in this alternative could be possible for at least two reasons: 1) the wide range of nutrients from the organic matter of the green manure positively contributed to the nutritional balance of the plants, favoring crop health and 2) the incorporation of green manure promoted the growth and activity of microorganisms in the soil and those introduced through the broths, especially the rhizosphere broth (Viteri *et al*., 2005; Méndez and Viteri, 2007), generating a microbial interaction that was not favorable to the pathogens. The first consideration is based on the trophobiosis (Restrepo, 2000) theory that organic defenses of the plant are determined by balanced nutrition, which prevents the formation of free sugars and amino acids that are essential for

TABLE 2. Effects of sustainability alternatives on the incidence of diseases (%) in growing onion bulbs. Cucaita, Boyaca.

Source of variation	Days after transplant					
	30	45	60	75	90	105
Farm (A)						
Luvita	40.5	50.5	47.6	99.0	99.0	98.7 b
El Arenal	43.5	49.1	28.5	29.4	46.7	87.2 a
Significance	NS	NS	NS	1%	1%	5%
Alternative (B)						
BCmSB4F	72.2 c	69.5 c	35.5	75.0	76.0	97.7
BCmRBSB4F	39.5 b	69.5 c	37.2	63.0	86.5	92.2
GmRBSB4F	29.0 a	32.1 a	32.7	62.5	67.2	91.7
Regional control	27.2 a	29.0 a	46.7	56.2	61.7	90.2
Significance	1%	1%	NS	1%	5%	NS
Interaction(A x B)	NS	NS	NS	1%	1%	NS

BCmSB4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer; NS, not significant. Means in the same column followed by the same letter are not significantly different according to Duncan's test ($P \leq 0.05$).

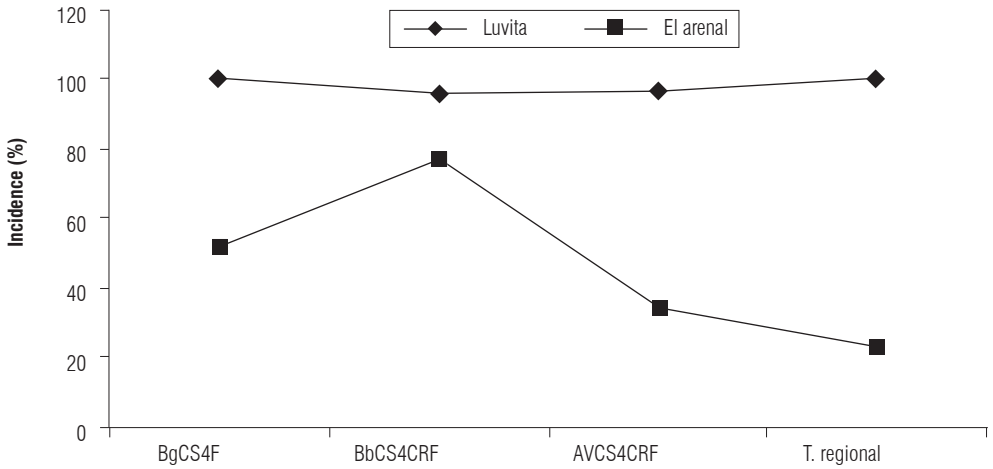

FIGURE 1. Farm x alternative interaction related to the variable of incidence of diseases 90 dat. Cucaita, Boyaca. BCmCS4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, Bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer; RC, regional control.

the invasion and spread of fungi, bacteria and viruses (Agrios, 1996).

The ANOVA also showed that at 75 and 90 dat a farm x sustainability alternative interaction 1% existed, indicating that at this time of crop development the alternatives effect on crop health depended on farm conditions. While in Luvita incidence rates were close to 100%, in El Arenal, they were considerably lower, as illustrated in Fig. 1. According to Agrios (1996), factors which mainly influence the initiation and development of crop diseases are temperature, humidity, light, nutrients and pH of the soil. In this particular study, the differences were mainly seen for pH and nutrient content in the soil (Tab. 1).

As for pH, Luvita farm soil may have favored the presence of *Peronospora destructor*, *Alternaria porri*, *Stemphylium* sp. and *Sclerotium cepivorum*, known in the region as the main fungi that cause disease in onion crops. The influence of pH could be exercised directly on the pathogen (Agrios, 1996) or through the weakening of the plant due to nutrition imbalance (Tisdale *et al*., 1993). The prevalence of fungi in the microbial community in acid soils has been reported by several authors (Carlile and Watkinson, 1996; Sylvia *et al*., 2005). In relation to nutrient content, the differences were in terms of phosphorus (P), potassium (K), iron (Fe) and zinc (Zn); highlighting the high P and K content at El Arenal. Although fungi require a wide range of nutrients in higher amounts for their growth (Carlile and Watkinson, 1996), it has been reported that higher P contents reduce the severity of some diseases and that K can reduce or increase the severity through its direct effect on the stages of the establishment of the pathogen in the host (Agrios, 1996). This allows us to infer that

the high content of P and K in the soil of El Arenal was a major factor in the lower incidence of diseases in the crop.

It is also important to emphasize that among the chemical elements introduced through microbial broths and bocashi (Viteri *et al*., 2005, 2008b), calcium (Ca), copper (Cu) and mainly sulfur (S) are noted as controllers of the determined pathogens. S inhibits the growth of fungi and bacteria (Bruzon, 1998) by blocking cell respiration and inhibition of nucleic acid and protein synthesis (Cruz, 2001), Ca greatly influences the types and species of pathogens (Castaño *et al*., 1996) and Cu is recognized for its broad antifungal action (Agrios, 1996).

Plant height and stem diameter

The effects of the sustainability alternatives on these two variables are presented in Tab. 3. Analysis of variance showed that plant height differences were significant for the farms 5% at 120 dat, obtaining the greatest height at El Arenal. Statistical analysis also showed significance for the farm x alternative interaction in the variables plant height 5% at 60 dat and stem diameter 5% at 60 and 75 dat. Overall, the data in Tab. 3 showed that in the first phase of development of the cultivation, Luvita exceeded El Arenal both in plant height and stem diameter, but as the development advanced, the El Arenal crop equaled or surpassed Luvita, suggesting important agronomic differences by the end of the growing season, as shown in Tab. 4.

Effects of alternatives on crop production

The results in Tab. 4 show that at the farm level, there were highly significant differences in weight and yield of healthy bulbs and significant differences for bulb diameter. The yield reported for El Arenal was within the range (40-50 t ha^{-1}) usually obtained through the use of agrochemicals by farmers in Cucaita (Méndez, 2007). For the alternatives, there were no significant differences in any of the evaluated variables in relation to crop production. The relation for weight of diseased bulbs presented in the farm x alternative interaction (Fig. 2) indicates that this variable is affected by the alternatives and the conditions of the farm. According to Fig. 2, the losses due to the number of diseased bulbs were lower at Luvita. At El Arenal, the losses were higher with the BCmRBSB4F alternative and intermediate with the GmRBSB4F alternative. Considering that the fungus *S. cepivorum* is the major causative agent of disease in bulbs in Cucaita, it is contrasting that the effectiveness of the green manure alternative has not been the best, since it includes radishes, a species that has shown potential for significantly lower infestation levels of *S. cepivorum* in soil (Alba and Vargas, 2007; Castellanos and Rojas, 2007; Velandia and Viteri, 2008). The lack of a more effective result from this alternative could be for two reasons: 1) the bulbs in addition to *S. cepivorum* can be damaged by other pathogens and 2) *S. cepivorum* in the cultivated lots appears in spots clearly defined, thus hindering the scope and effectiveness of any alternative.

The better production results reported for El Arenal (Tab. 4) are consistent with the fact that the soil of that farmoffered better conditions for crop growth and development, especially in terms of pH and content of P and K (Tab. 1), therefore the disease incidence rates in the crop were also lower, especially at the end of the growing season (Tab. 2).

Considering the amount of fertilizer (950 kg ha^{-1}) and fungicides [Dithane® 80 WP (mancozeb), 30 kg; Forum® 500 WP (dimetomorph), 8 kg; Acrobat® WP (dimetomorph

TABLE 3. Effects of the sustainability alternatives on plant height and stem diameter in onion crops. Cucaita, Boyaca.

Source of Variation	Plant height (cm)					Stem diameter (mm)				
	Days after transplant									
	60	75	90	105	120	60	75	90	105	120
Farm (A)										
Luvita	62.7	61.5	63.7	58.6	39.1 a	16.8	17.0	17.7	15.4	12.9
El Arenal	54.5	57.2	66.5	57.7	51.2 b	15.2	15.0	19.5	17.2	13.4
Significance	1%	NS	NS	NS	5%	1%	5%	NS	NS	NS
Alternative(B)										
BCmSB4F	61.5	63.2	71.0	63.5	45.7	15.0	14.7	20.0	18.2	13.5
BCmRBSB4F	54.7	60.0	61.5	60.7	48.0	15.0	16.5	18.2	15.5	12.5
GmRBSB4F	60.0	57.0	64.2	53.0	43.2	16.7	16.7	19.0	17	12.5
Regional control	58.2	57.2	63.7	55.5	43.7	17.5	17.0	17.2	14.5	14.0
Significance	NS	NS	NS	NS	NS	1%	NS	NS	NS	NS
Interaction (AxB)	5%	NS	NS	NS	NS	5%	5%	NS	NS	NS

BCmCS4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer. NS, not significant. Means in the same column followed by the same letter are not significantly different according to Duncan's test ($P \leq 0.05$).

+ mancozeb) 10 kg and sectin (fenamidone + mancozeb), 10 kg] that were applied in the regional control, it is noteworthy that the evaluated alternatives had the potential to equal production of the conventional farming method from the start. According to previous recommendations (Méndez and Viteri, 2007), each of the alternatives includes a source of organic matter (bocashi or green manure) that is essential to ensure not only the multiplication of the variety of microorganisms introduced through the bocashi or the trophobiotic broths (Viteri *et al.*, 2005) but also the native soil biota (Poincelot, 2004). Meanwhile, both bocashis and the trophobiotic broths provide nutrients (Viteri *et al.*, 2005, 2008b) that are critical to the growth and development of the crop. According to Hochmuth *et al.* (2004), B is important for the normal development of the meristem and root tips and Zn for the activation of enzymes required for the synthesis of indole acetic acid. Peña and Davila (1999) claim that zinc sulfate promotes oil production significant to onion flavor and yield, according to Castro *et al.* (2007), because Zn promotes better expression or layers of the bulb. Mg stimulates the onset of bulbing and is involved in the absorption of N, K, and P (Mengel and Kirby, 2001; Marschner and Horst, 1995). Ca stimulates root growth (Bruzon, 1998) and influences the absorption of N, Mg and K (Castro, 1998).

With the fact that production variables showed no differences between the alternatives, it should be clarified that the amount of organic matter incorporated through the green manure alternative (2.4 t ha^{-1} Luvita and 3.4 t ha^{-1}

TABLE 4. Effect of sustainability alternatives on some of the variables related to crop production. Cucaita, Boyaca.

Source of variation	Healthy bulb (kg)	Diseased bulb (kg)	Bulb diameter (cm)	Yield (kg ha^{-1})
Farm (A)				
Luvita	34.8 b	0.17	7.1 b	35.0 b
El Arenal	42.1 a	0.54	8.0 a	42.7 a
Significance	1%	NS	5%	1%
Alternative (B)				
BCmSB4F	38.5	0.1	7.6	38.6
BCmRBSB4F	40.4	0.6	7.5	41.0
GmRBSB4F	32.8	0.4	7.6	33.1
Regional control	42.4	0.3	7.5	42.6
Significance	NS	NS	NS	NS
Interaction (A x B)	NS	1%	NS	NS

BCmCS4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer. Means in the same column followed by the same letter are not significantly different according to Duncan's test ($P \leq 0.05$).

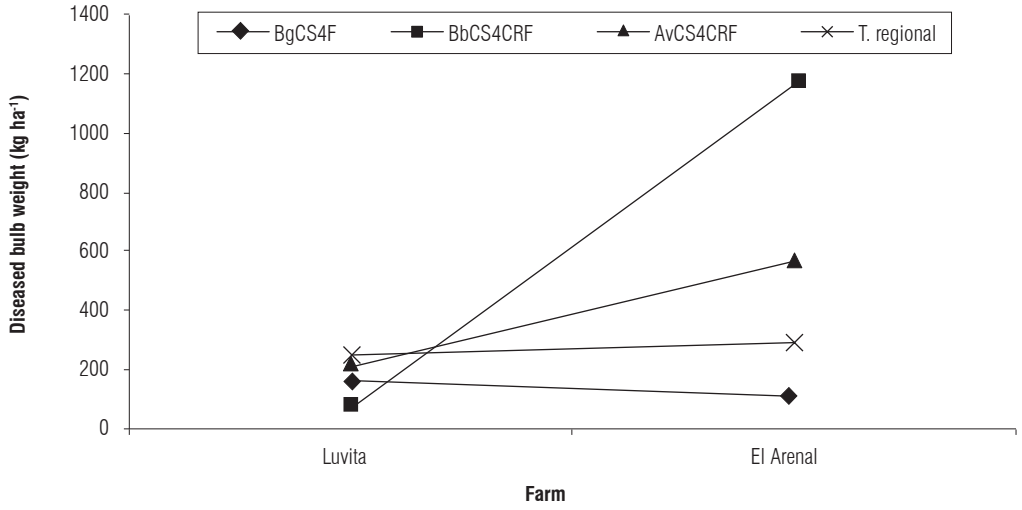

FIGURE 2. Farm x alternative interaction in relation to the variable diseased bulb weight. Cucaita, Boyaca. BCmCS4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer.

El Arenal) was much lower than that of bocashi (6.0 t ha^{-1}). The idea of allowing growth in the green manures for only two months was to equal the time taken for the development of the trophobiotic broths and bocashi, unfortunately the amount of dry biomass produced in that period of time was much lower. However, the results of research conducted with other green manure in cold climate regions of Boyaca indicate that depending on the local agro-ecological conditions, the maximum dry matter accumulation occurs between 75 and 120 dat, with yields ranging between 4.5 and 34 t ha^{-1}, excluding the contribution of the root system (Orjuela, 2000; Tamayo, 2001; Viteri, 2002; Viteri and Méndez, 2003; Viteri and Velandia, 2006; Viteri *et al*., 2008a). This suggests that in the case of green manure, the best option is to delay the date of its use until maximum dry matter accumulation and thus be able not only to meet but far exceed the 6.0 t ha^{-1} with bocashi, an amount that was used following the protocol of previous research (Méndez and Viteri, 2007). The high contribution of organic matter from green manure obviously accelerates the recovery process for the physical, chemical and biological soil properties for development and sustainability of the crop.

Cost: benefit

The projected economic benefits that farmers would receive when applying these alternatives are presented in Tab. 5. All alternatives were profitable at very acceptable levels especially the BCmRBSB4F alternative that exceeded even the regional control. This observation allows us to infer that if the onion crop is implemented using bioinputs that would effectively lead to the recovery of the productive capacity of the soils and balanced crop nutrition, application of fertilizers and pesticides may well be reduced without affecting profitability; on the contrary, income may be higher and guaranteed in the future with the resulting impact on sustainable farming.

The profitability of the green manure alternative was not the best due, no doubt, to the very low input of organic matter compared to bocashi manure. However, with respect to this alternative, it has already been emphasized that if the use of green manure occurs with maximum dry matter accumulation, the potential is such that it could far exceed the amount of organic matter incorporated through bocashi (6 t ha^{-1}) and therefore also the effects on the sustainability and profitability of farming. Even under conditions with acid sulphate soils, dry matter intake from the radishes could reach 8 t ha^{-1} (Hernández and Viteri, 2006). It should also be noted that the radishes can contribute to the recovery of production lots of onions that have been lost due to *S. cepivorum* infestation (Alba and Vargas, 2007; Castellanos and Rojas, 2007; Velandia and Viteri, 2008). Other advantages of green manures to the farmer are: 1) the seed can be produced on farms and become an internal input, helping to reduce production costs and 2) it is a practice that can be used by small, medium and large farmers because it allows mechanization.

It is anticipated that the bocashi alternative (BCmSB4F) is costly and wasteful. Expensive because the price of the manure used is high, because it must be composted to avoid the risk of infesting the soil with *Fusarium* sp. (Viteri *et al*., 2005) and properly composted manure is wasteful because it is not easy to get in the market.

The analysis and interpretation of the results of this research verify the potential of the alternatives GmRBSB4F and BCmRBSB4F for sustainable cultivation of onion in Cucaita. The implementation of these alternatives with the sustainable approach proposed by Altieri and Anderson (1986); Altieri (1995); Altieri and Nicholson (2000), requires understanding and effort not only from producers but also from public and private entities, that envision the management of natural resources not only from the economic point of view but also value other aspects critical to the welfare and progress of the communities such as the impact to the environment, production resources, public health and the preservation of local culture and small farms.

Conclusions

Regardless of the sustainability alternative, agroecological conditions of the farm are critical to disease incidence and crop production. Consistent with the lower incidence

TABLE 5. Profitability of sustainable alternatives for growing onion. Cucaita, Boyaca. 2004B.

Treatment	Production cost (ha/$)	Onion yield (Kg ha^{-1})	Production value ($)*	Profit ($)
BCmSB4F	8,675,000	48,250	13,510,000	4,835,000
BCmRBSB4F	8,360,000	51,250	14,350,000	5,990,000
GmRBSB4F	7,870,100	41,375	11,585,000	3,714,900
Regional control	9,088,000	53,250	14,910,000	5,822,000

BCmCS4F, bocashi-chicken manure, super broth four and fertilizer; BCmRBSB4F, bocashi-cow manure, rhizosphere broth, super broth four and fertilizer; GmRBSB4F, green manure, rhizosphere broth, super broth four and fertilizer. $, Colombian Pesos (COP). * Price per kg in the local market: $280.

of diseases, El Arenal produced the highest healthy bulb weight, bulb diameter and yield.

The differences between the alternatives were significant only in incidence of diseases at 30 and 45 dat, with the green manure alternative excelling, together with the regional control.

During the period of vegetative development of the crop the effect of the alternatives on disease incidence, plant height and stem diameter and at harvest on diseased bulb weight depended at certain times on the conditions of the farm.

Notably, the BCmRBSB4F alternative indicates that from the biological point of view in the onion crop, it is possible to match, from a production standpoint, and outperform, in terms of profit, the conventional application of agrochemicals.

For profit, the three alternatives were favorable, but especially the BCmRBSB4F alternative ($5,990,000COP) which exceeded the regional control ($5,822,000COP).

The results show that the alternatives GmRBSB4F and BCmRBSB4F have the most potential and are the most viable for sustainable onion production in Cucaita.

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