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ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

DIVERSITY AND ABUNDANCE OF INSECTS IN POTATO CROP CAPTURED USING COLOR TRAPS IN CUSCO, PERU

DIVERSIDAD Y ABUNDANCIA DE INSECTOS EN PAPA EMPLEANDO TRAMPAS DE COLORES EN CUSCO, PERÚ

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ABSTRACT

Insects associated with potato in the Huatta community (Pisac, Calca, Cusco) were evaluated using color traps. The traps were plastic trays with water and detergent placed in the field, the evaluated colors were: white, yellow, green, red and blue. Two evaluations were made, one in November and the other one in December 2019. Identifications were made to the family level. The analyzes performed were: multifactorial ANOVA, ANOSIM, non-metric multidimensional scaling and SIMPER. Statistical differences were found between the colors evaluated and dissimilarity between them. In total, 30 families of insects have were found associated with the potato crop. The color traps used in the present research show independence in the number of families captured: Yellow (1.47), Blue (1.36), Red (1.35), White (1.32) and Green (1.21). The percentage of contribution of the families collected in the color traps used has been determined. Collembola (10.94), Drossophilidae (9.75), Chrysomelidae (3.75), Phoridae (3.44) and Anthomyiidae (3.13) showed the more important contribution in SIMPER analysis. A high positive correlation was found between the colors white with yellow, and red with blue.

Keywords: color traps – Cusco – pests – potato

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RESUMEN

Se evaluó la diversidad de insectos asociados a un cultivo de papa en la comunidad de Huatta (Pisac, Calca, Cusco), Perú empleando trampas de colores blanco, amarillo, verde, rojo y azul. Las trampas fueron bandejas de plástico con agua y detergente colocadas en el interior de los cultivos para determinar el efecto del color de las trampas en las evaluaciones de las comunidades de insectos. Se hicieron dos evaluaciones, una en noviembre y otra en diciembre del 2019. Las identificaciones se hicieron hasta el nivel de familia. Los análisis realizados fueron: ANOVA multifactorial, ANOSIM, escalamiento multidimensional no métrico y SIMPER. Se encontraron diferencias estadísticas entre los colores evaluados y los índices de disimilitud. En total se colectaron 30 familias de insectos asociados al cultivo de papa. Las trampas de colores mostraron independencia en el número de familias capturadas: amarillo 1.47, azul 1.36, rojo 1.35, blanco 1.32, verde 1.21. Se determinó el porcentaje de contribución de las familias colectadas para cada color de trampa. Collembola (10,94), Drossophilidae (9,75), Chrysomelidae (3,75), Phoridae (3,44) and Anthomyiidae (3,13) mostraron la contribución más importante en el análisis SIMPER. Se encontró alta correlación positiva entre los colores blanco con amarillo, rojo y azul.

Palabras clave: Cusco – papa – plagas – trampas de color

INTRODUCTION

The potato crop hosts to numerous species of insects that attack all the organs of the plant (Radcliffe, 1982) and, due to its economic importance, it has been the subject of several integrated management strategies (Carrera & Cermeli, 2001; Rondon *et al.*, 2003; Galindo & Español, 2004; Rondon, 2010; Cañedo *et al.*, 2011).

Among the main strategies for monitoring and controlling pests in potatoes and other crops are: the use of pheromones (Foster & Harris, 1997; Carrizo, 1998; Weinzierl *et al*., 2005; Farfán & Iannacone, 2009), color traps (Chavez & Raman, 1987; Boiteau, 1990; Cabello *et al*., 1991; Rodríguez & Vásquez, 2000; Atakan & Canhilal, 2004; Jiménez *et al.*, 2004; Bravo-Portocarrero *et al.* 2020), light traps (Boiteau, 2009; Day & Reid, 1969) and others.

Color traps has demonstrated to be effective to monitoring and control several pests, by example, *Lygus* sp. (Blackmer *et al.*, 2008), aphids (Boiteau, 1990), Chrysomelidae (Boiteau, 2009), Thripidae (Cardenas & Corredor, 1989; Carrizo, 1998; González *et al*., 1999; Cabello *et al*., 1991; Jiménez *et al*., 2004; Demirel & Yildirim, 2008; Virgen *et al*., 2011), Cicadellidae (Arismendi *et al*., 2009), Agromyzidae (Chavez & Raman, 1987), Curculionidae (Tapia *et al.* , 2010) and Braconidae (Mena-Mociño *et al.*, 2016).

Although there is no updated record of potato pests in Cusco, but several general references can be taken (Carrasco, 1967; Escalante *et al*., 1981; Huamaní, 2020; Kroschel *et al.*, 2020).

The project was proposed to: a) determine the diversity and abundance of insects associated with potato crop, b) determine the effect of traps colors for the evaluation of the insect community associated with potato crop.

MATERIALS AND METHODS

The work was carried out in a commercial potato field and it was not installed by the authors, the potato field is located at Huatta community of

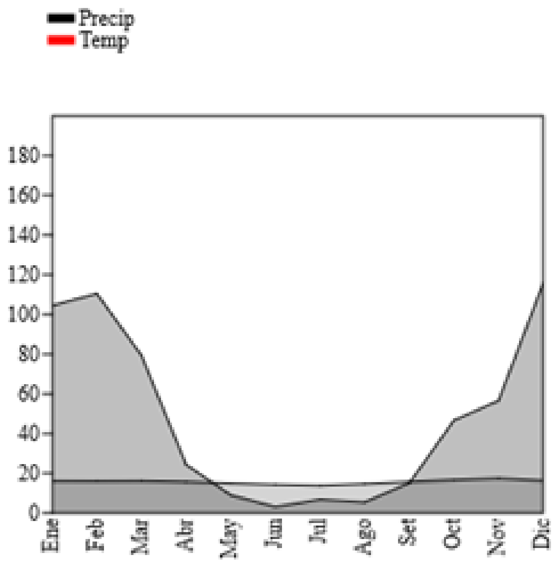

Figure 1. Precipitation and temperature of the Huatta community (Pisac, Calca).

Huata (Pisac, Calca) with the following data: Altitude: 3423 m, South latitude: 13° 27'21.87 ", West longitude: 71° 52'20.43 ". The climatic conditions are observed in Fig. 1.

Sampling
Five-color plastic trays were setted: white, yellow, green, red and blue, each trap was 20 cm length and 10 cm width and 8 cm depth. The trays were filled with water up to 50% of their total capacity, 1 g of detergent was added to break the surface tension.

Two samplings were carried out, one in November and the other one in December 2019, using a piece of organza cloth to filter the water from each trap. The collected material was transferred to bottles with alcohol, one bottle per tray, and it was taken to the Laboratorio de Entomología de la Universidad Nacional de San Antonio Abad del Cusco (CEUC-UNSAAC), Perú.

Trays were arranged randomly, three repetitions were used for each color, making a total of 15 trays for each evaluation(Southwood, 1966).

Identification
All the material was separated by morphotypes and identified down to the family level, except in some cases where it reached genus and/or species. For the identification, the Triplehorn & Johnson (2005) keys were used.

Analysis
The counts were arranged in an Excel® matrix of families by colors. A normality test was performed and the data were transformed to $\sqrt{x} + 1$. With the transformed data, a multifactorial ANOVA test was done taking as factors: colors, families and the interaction colors by families with the Statistica 8.0® program. In cases where significant differences were found, a Tukey test was performed ($\alpha = 0.05$). The diversity was determined using the Simpson index:

$$c = \sum_{i}^{st} pi2$$

and 1-D to determine diversity as well as the estimator Chao1. This estimator is based on abundance, it refers to the abundance of individuals that belong to a certain class in a sample, which can be site, quadrant, trap, etc. It is based, fundamentally, on the presence of species represented only by one individual in the sample and the number of species represented by two individuals in the sample (Escalante, 2007; González-Oreja *et al.*, 2010).

Additionally, multidimensional scaling and ANOSIM were performed to determine the differences between colors with the PAST® program. Multidimensional scaling comprises a family of multivariate procedures that make it possible to represent the proximities between a set of elements as distances in a space. The NMDS (Non-Metric Multidimensional Scaling) uses a monotonous least squares regression —(López-González & Hidalgo, 2010). The Similarity Analysis (ANOSIM) is a non-parametric test that is used to determine the statistical significance of the groups by means of a cluster analysis. The program calculates the *R* statistic that denotes dissimilarity between groups if its value approaches or exceeds 1 (Giraldo, 2015). A correlation matrix was performed using Pearson´s linear correlation coefficient to determine the association between the evaluated colors with SPSS 17® program.

Due to there are significant differences between families the taxa that contributed to the most of these differences were identified using the SIMPER analysis (Clarke & Warwick, 2001; Cruz-Motta, 2007).

Ethic aspects: The authors have followed the ethical regulation of the country.

RESULTS

ANOVA shows statistically significant differences for colors, families and families by color interaction (Table 1).

Table 1. Response of insect families to color traps in potato cultivation

White	Yellow	Green	Red	blue
1.32 bc*	1.47 a	1.21 c	1.35 b	1.36 a b

ANOVA
Colors (P = 0.00000)
Families (P = 0.00000)
Families x colors (P = 0.00000)

*Different letters for each color indicate statistically significant differences (LSD, α = 0.05)

The Simpson Index shows greater diversity (1-D = 0.90) for red color, but the value of Chao 1 indicates the greatest number of families could correspond to yellow (Chao1 = 26) (Table 2).

The Non-Metric Multidimensional Scaling shows dissimilarity between the colors used (Fig. 2)

Table 2. Number of families, Simpson's diversity index (1-D) and Chao1 estimator for color traps in potato cultivation.

Color	# Families	Simpson Index (1-D)	Chao1
White	22	0.87	24
Yellow	25	0.88	26
Green	20	0.80	22.5
Red	20	0.90	20
blue	22	0.88	22.75

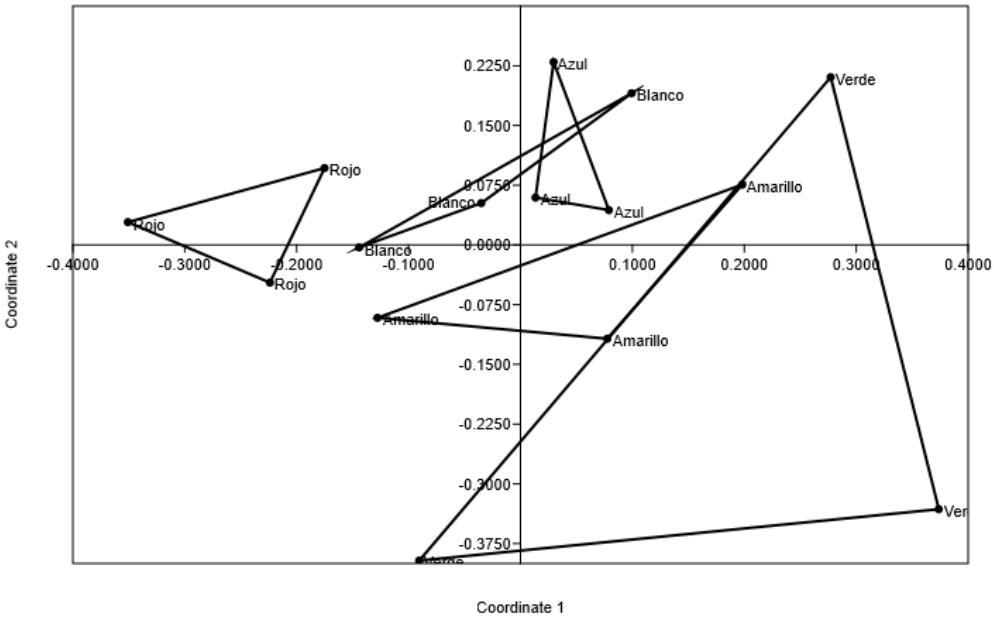

Figure 2. Non-metric multidimensional scaling for insects captured by color traps in potato cultivation.

Pearson´s linear correlation coefficient shows a greater association between color pans used to evaluate insects associated to potato cultivation. (Table 3).

The dissimilarity analysis shows an *R* value is close to 0: 0.22 (P = 0.03), which indicates dissimilarity between the evaluated colors (Table 4).

Table 3. Pearson´s linear correlation coefficient between color pans in potato cultivation.

	White	Yellow	Green	Red	Blue
White					
Yellow	0.887**				
Green	0.403*	0.585**			
Red	0.530**	0.420*	0.072		
Blue	0.859**	0.846**	0.590**	0.536**	

** correlation is significant at 0.01 level. * correlation is significant at 0.05 level

Table 4. ANOSIM (Dissimilarity Analysis) values for the colors used.

N permutation	9999
Average range of dissimilarity within groups	42.8
Range prom and gave the dissimilarity between groups	54.7
A:	0.22
P	0.03

The SIMPER analysis shows the contribution percentage of the identified families (Table 5).

Table 5. SIMPER analysis for number of individuals by families identified in color pans evaluated in potato cultivation.

Taxon	Av. Dissim	Contrib. %	Cumulative%	Mean 1	Mean 2
Collembola	10.94	21.51	21.51	14.3	6.67
Drosophilidae	9,751	19.17	40.67	9.33	7
Chrysomelidae	3,752	7,375	48.05	2.33	3
Phoridae	3,441	6,764	54.81	3.67	5.67
Anthomyiidae	3,136	6,163	60.97	3	4.33
Cicadellidae	2,312	4,545	65.52	1.67	2.33
Cecidomyiidae	1,806	3.55	69.07	1	2.33
Muscidae	1,806	3.55	72.62	2	0.667
Tipulidae	1,774	3,487	76.1	0.667	2
Ptiliidae	1,412	2,775	78.88	1.33	1
Aphididae	1,372	2,696	81.58	0.333	1.33
Pteromalidae	1,308	2,571	84.15	1.33	1.33
Araneae	1,225	2,407	86.55	0.333	1
Braconidae	1,049	2,062	88.62	0.667	0.667
Sarcophagidae	0.8907	1,751	90.37	0.667	0.333
Dolichopodidae	0.8646	1,699	92.07	0.333	0.667
Bibionidae	0.801	1,574	93.64	0	0.667
Staphylinidae	0.7847	1,542	95.18	0	0.667
Psyllidae	0.4245	0.8345	96.02	0	0.333
Chloropidae	0.4245	0.8345	96.85	0	0.333
Pergidae	0.4245	0.8345	97.69	0	0.333
Apidae	0.4245	0.8345	98.52	0	0.333
Calliphoridae	0.3805	0.748	99.27	0.333	0
Agromyzidae	0.372	0.7312	100	0.333	0
Tephritidae	0	0	100	0	0
Tachinidae	0	0	100	0	0
Syrphidae	0	0	100	0	0
Coccinellidae	0	0	100	0	0
Sciaridae	0	0	100	0	0
Mycetophilidae	0	0	100	0	0

DISCUSSION

Color traps have demonstrated to be an efficient technique to evaluate and control several pest species. However, most studies with color traps have been done almost exclusively for monitoring and control of specific pests, especially trips and cicadellids (Cardenas & Corredor, 1989; Cabello *et al*., 1991; Carrizo, 1998; González *et al*., 1999; Jiménez *et al*., 2004; Demirel & Yildirim, 2008; Virgen *et al*., 2011), Agromyzidae (Chavez & Raman, 1987), Dryoptoridae (Tapia *et al*., 2010) and Braconidae (Mena-Mociño *et al.*, 2016).

In this case, an evaluation was made with the total of species captured and the results show that the use of color traps was a good instrument to detect insect species in potato.

Statistical differences show each color, is acting on a determined number of families, how it has been indicated in several references (Chavez & Raman, 1987; Boiteau, 1990; Dreistadt *et al.*, 1998; Atakan & Canhilal, 2004; Demirel & Yildirim, 2008). The present research showed that the color traps can attract a large number of species not necessarily harmful to the crop. Thus, more than 30 families are reported (Table 5) but only some of them contain species that are harmful to potato crop.

A possible limitation for this type of research is that the insect fauna associated with potato cultivation in Cuzco is not adequately known, and, in many cases, species such as "sp." or "spp" are still reported (Carrasco, 1967; Escalante *et al.*, 1981; Huamaní, 2020), even in species of great economic importance such as the "skeletonizer" (García-Sinche & Catalán-Bazán, 2011) or the potato moth.

The multidimensional scaling shows independence between the evaluated colors even when a slight overlap between the blue and white colors is observed (Fig. 2), which one is confirmed by observing the values found in the pair analysis (Table 3) and the ANOSIM values, with an *R* value close to 0 (Table 4).

Regardless of the results found so far, it can be assumed that it is feasible to use color traps to monitor insect populations in the potato crops. This will be more effective with an adequate knowledge of the insects associated with the crop, and not necessarily using other types of traps (Atakan & Canhilal, 2004; Weinzierl *et al.*, 2005; Boiteau, 2009).

The fact of collecting many families, it does not necessarily indicate a high efficiency of the traps, if this is not accompanied by an adequate recognition of the attracted insects. So, Chrysomelidae, with a contribution of 7,375 contains several of the most economically important species for crop, by example, *Epitrix* spp., *Diabrotica* Chevrolat, 1837 (several species), *Calligrapha curvilinea Stal, 1859*, etc. The Cicadellidae family, with a contribution of 4,545%, includes species of economic importance, such as *Empoasca* (Walsh, 1862) and other genera. However, it is necessary to point out the case of the Pergidae family, with a contribution of 0.8345%, which includes one of the species considered to be a key pest for potato crops in the highland of Peru and is associated with yellow traps: *Tequus ducra* (Smith, 1980) (Hymenoptera, Pergidae).

These species are considered very important for potato crop and they can cause great economic importance damages (García-Sinche & Catalán-Bazán, 2011). However, until now, there are not an adequate strategy for its management, mainly because farmers and technicians do not make a proper differentiation between adults or their immature stages (Yabar, personal observation).

Therefore, the yellow traps used in the present research are inexpensive and easy to manage, and these could be a suitable alternative to early detection of populations of these insects and other pests and these techniques can also be applied to local management strategies.

In total, 30 families of insects have been found associated with potato crop. The color traps used in the present research show independence in the number of families captured: Yellow 1.47, Blue 1.36, Red 1.35, White 1.32, Green 1.21. The percentage of contribution of the families collected, in the color traps used, has been determined. Collembola (10.94), Drossophilidae (9.75), Chrysomelidae (3,75), Phoridae (3,44) and Anthomyiidae (3.13) showed the more important contribution in SIMPER anaylisis.

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