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Effect of intercropping of cabbage, lettuce, parsley and chard on weed incidence and cabbage yield

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Efecto de la asociación repollo, lechuga, perejil y acelga sobre la incidencia de malezas y el rendimiento del repollo

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ABSTRACT

Keywords:
Brassica oleracea L
Equatorial diameter
Lactuca sativa L
Polar diameter

The present study aimed to evaluate the effect of the association of cabbage, lettuce, parsley and chard on the incidence of weeds and cabbage yield parameters. The research was conducted on the Facultad de Ciencias Agrarias campus of the Universidad de Concepción, Paraguay. The treatments consisted of cabbage (T1), cabbage+lettuce (T2), cabbage+chard (T3), and cabbage+parsley (T4). The trial was laid out in Randomized Complete Block Design (RCBD) with four treatments and six replications, totaling 24 Experimental Units (EUs). Measurements included the percentage of weed incidence, cabbage yield (ton ha^{-1}), and equatorial and polar diameter of the head (cm). These mean values were subjected to analysis of variance (ANOVA) and when significant differences were found between treatments, the mean comparison was performed using the Tukey test at 5%. No significant differences were recorded for cabbage yield, equatorial, and polar diameter (P>0.05). It is concluded that the plant species used in this research in consortium with cabbage positively influenced reducing weed incidence and increasing cabbage yield, but did not significantly affect the equatorial and polar diameters of cabbage heads.

RESUMEN

Palabras clave:
Brassica oleracea L
Diámetro ecuatorial
Lactuca sativa L
Diámetro polar

El presente trabajo tuvo como objetivo evaluar el efecto de la asociación de repollo, lechuga, perejil y acelga sobre la ocurrencia de malezas y parámetros de rendimiento del repollo. La investigación se realizó en el campus de la Facultad de Ciencias Agrarias de la Universidad de Concepción, Paraguay. Los tratamientos utilizados fueron repollo (T1), repollo+lechuga (T2), repollo+acelga (T3) y repollo+perejil (T4). El diseño utilizado fue el de parcelas subdivididas con cuatro tratamientos y seis repeticiones, totalizando 24 Unidades Experimentales (UE). Las determinaciones evaluadas fueron porcentaje de incidencia de malezas, rendimiento del repollo (ton ha^{-1}) y diámetro ecuatorial y polar de la cabeza (cm). Estos valores fueron sometidos a un análisis de la varianza (ANOVA) y, cuando se encontraron diferencias significativas entre los tratamientos, la comparación de medias se realizó mediante la prueba de Tukey al 5%. No se registraron diferencias significativas para el rendimiento del repollo, el diámetro ecuatorial y polar (P>0,05). Se concluye que las especies vegetales utilizadas en este estudio en consorcio con el repollo influyeron positivamente en la reducción de la incidencia de la maleza y en el aumento del rendimiento del repollo, pero no afectaron significativamente a los diámetros ecuatorial y polar del repollo.

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Horticulture is a significant development and economic activity engine with substantial social and economic value. It is a source of employment throughout the entire value chain, plays an important role in regional economies, and is a crucial factor for countries seeking to optimize vegetable consumption in quantity, diversity, and quality (Castagnino et al. 2020).

Like other crops, horticultural species are susceptible to weed interference's negative effects (Fukushi 2016). The weeds most frequently reported by De Egea et al. (2018) in Concepción, Paraguay are *Sagittaria montevidensis, Commelina diffusa* Burm., *Commelina platyphylla* Klotzsch ex Seub., *Cyperus rotundus* L., *Cenchrus equinatus* L., *Echinochloa crus-galli* (L.) O. Schulz, *Digitaria ciliaris* (Retz.) Koern., *Hymenachne amplexicaulis* (Rudge) Nees, *Megathyrsus maximus* (Jacq.), *Amaranthus viridis* L., etc.

The rapid vegetative growth of these weeds has the potential to directly affect crop yield and quality if not controlled in a timely and effective manner (Rojas et al. 2017). Therefore, management practices should be efficient and consider the most appropriate management for the crop (Fukushi 2016).

According to MacLaren et al. (2020) to achieve the goal of sustainable weed management it is suggested that an alternative ecological approach be adopted where the goal is not the total elimination of weeds, but an understanding of what characteristics of agroecosystems confer flexibility to noxious weed invasions and at the same time encourage a diverse weed population to sustain ecosystem services.

In the consortium, the presence of one or more support crops can help suppress weeds by following them without interfering with the development of the crop of economic interest (Castagnino et al. 2020). Therefore, the use of intercropping as a weed management strategy will help reduce the occurrence of weeds and minimize contamination caused by chemical crop protection (Ribas et al. 2020).

Therefore, this research aimed to evaluate the effect of the association and monoculture of cabbage, lettuce, parsley and chard on the occurrence of weeds and cabbage yield parameters.

MATERIALS AND METHODS

The research was conducted on the Facultad de Ciencias Agrarias campus of the Universidad Nacional de Concepción, located 2 km from the city of Concepción, Paraguay. The study was carried out from November 2022 to April 2023. The mean annual precipitation and temperatures can be appreciated in Figure 1.

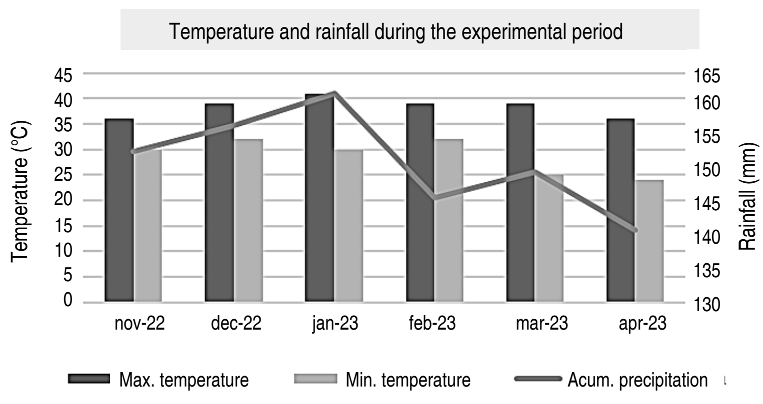

Figure 1. Monthly precipitation and maximum and minimum temperatures during the experimental period (DINAC 2023).

The soil preparation phase started in November. This involved the conventional preparation of the soil, the lifting of the planks, the implementation of a base fertilization regimen, the installation of a drip irrigation system, and the deployment of a half-shade net.

The plant species were planted as follows: the cabbage seeds were initially sown in January. Once the plants had emerged and reached three weeks, two additional species were introduced: parsley and chard. Subsequently, lettuce seedlings that had been cultivated in previously prepared planting trays were transplanted after three weeks. In addition, irrigation was carried out twice a day, once in the morning and once in the afternoon.

The trial was laid out in a Randomized Complete Block Design (RCBD) with four treatments and six replications, totaling 24 Experimental Units (EUs). The dimension of each plot was 3.6 m^2, totaling 155.15 m^2. The treatments (T) consisted of using different vegetable species, with cabbage as the main crop, T1 cabbage (monoculture), T2 (cabbage + lettuce), T3 (cabbage + chard), and T4 (cabbage + parsley).

The distribution of plant population and spacing between plants and rows was as follows. In treatment 1, cabbage monoculture, a spacing of 0.45 x 0.65 m was used, totaling 12 plants per EU. In treatment 2, the combination of cabbage and lettuce, the spacing was 0.45 x 0.65 m for cabbage and 0.25 x 0.35 m for lettuce, totaling 6 cabbages and 20 lettuces per EU. In treatment 3, cabbage was combined with chard, using the same spacing for cabbage (0.45 x 0.65 m) and 0.25 x 0.45 m for chard, resulting in six cabbages and 16 chards per EU. Finally, for treatment 4, which consisted of the association of cabbage and parsley, a spacing of 0.45 x 0.65 m was used for cabbage and 0.125 x 0.25 m for parsley, obtaining six cabbages and 45 parsley plants.

Measurements were taken at 25, 40, and 55 days to determine the percentage weed incidence and cabbage head equatorial and polar diameter were determined at 55 days.

To determine the percentage of incidence of weeds at 25, 40 and 55 days, the random sampling method was adopted where the counting was done through the use of a wooden frame with the dimensions of 1x1 m (Grazziero et al. 2021), the weed count was carried out taking into account all the weeds found in that quadrant, in each part of the planks where the frame was thrown. Scissors, hoes, tape measures, plastic bags and the 1x1 m wooden frame were used for this measurement.

Cabbage yield was determined by weighing approximately 120 harvested cabbage heads using a precision electronic scale and averaging was expressed in tons per hectare. The equatorial and polar diameters of the harvested cabbage heads were measured using a centimeter ruler and averaged results were expressed in centimeters.

The data were subjected to analysis of variance (ANOVA) with the Agrostat® software (Barbosa and Maldonado 2015). In cases where significant differences were detected, mean comparison was performed using the Tukey test at 5% probability.

RESULTS AND DISCUSSION

Percentage of weed incidence

The results shown in Table 1 correspond to the determination of the percentage of weed incidence. It is observed that the lowest incidence rates are exhibited by treatments T1 (cabbage), T2 (cabbage + lettuce), and T3 (cabbage + chard).

Table 1. Mean Comparison for Weed Incidence Percentage (%).

Treatments	Weed Incidence (%)		
	25 days	40 days	55 days
Cabbage + parsley (T4)	75.24[b]	85.46[c]	81.00[b]
Cabbage + chard (T3)	74.30[b]	52.64[a]	33.66[a]
Cabbage (T1)	57.96[ab]	67.15[ab]	37.66[ab]
Cabbage + lettuce (T2)	44.92[a]	41.00[a]	30.66[a]
CV (%)	20.99	19.43	21.42
LSD	22.04	19.90	16.30

Means followed by different letters in the column differ statistically according to the Tukey test at a 5% probability of error, CV=Coefficient of Variance, LSD=Least Significant Difference.

It can be observed that at 25 days, the lowest incidence of weeds was obtained with treatments T1 (cabbage) and T2 (cabbage + lettuce). In contrast, at 40 and 55 days, the lowest results of weed incidence were observed in treatments T1 (cabbage), T2 (cabbage + lettuce) and T3 (cabbage + chard). It should be noted that all the identified weed species, observed both pre- and post-experimentation, are reported to be commonly occurring within the experimental area. The species include *Commelina diffusa* Burm., *Cyperus rotundus* L., *Digitaria ciliaris* (Retz.), *Cenchrus equinatus* L., and *Amaranthus viridis* L., along with the grass *Echinochloa crus-galli* (L.) O. Schulz.

In light of the findings of this determination, it can be posited that the coexistence of two species in a given area gives rise to competitive interactions with weeds, which ultimately prove deleterious to the weeds. Romero et al. (2024) define this phenomenon as phenotypic plasticity, defined as the ability of plants to respond to environmental stimuli with adjustments that generate different phenotypes over time or in different locations, modifying their functional traits. Consequently, plant growth is regulated by external factors, primarily through alterations in morphology, physiology, or biochemistry. In situations of stress, light and water are significant factors that exert a considerable influence on plant growth (Rahn et al. 2018).

As previously stated by Neupane et al. (2021) the practice of intercropping has been demonstrated to reduce the prevalence of weeds in agricultural systems. This is achieved by facilitating the capture of essential nutrients and other accessible resources. The presence of glucosinolate compounds in cruciferous plants has been identified as a contributing factor to weed suppression, due to their allelopathic effects. Furthermore, intercropping allows for the utilization of space and nutrients that would otherwise be unutilized by a single crop. This limits the space available for weed growth and proliferation.

However, to obtain efficient intercropping systems with bio-economic advantages, it is essential to manage the species to be cultivated effectively, as well as to consider production factors such as green manure, population densities of the component crops, and so forth (Lino et al. 2021).

Cabbage Yield

As indicated in Table 2, T2 exhibited superior outcomes in terms of weight, although its results are statistically equivalent to those observed in T1. A comparison of cabbage yield in monoculture and polyculture demonstrated that the crop in the monoculture system produced 36.975 (ton ha^{-1}) and 50,008 (ton ha^{-1}) in association with lettuce. However, statistically significant differences were observed when comparing the cabbage yield in association with lettuce and cabbage with chard and parsley.

Table 2. Mean Comparison for Yield (ton ha^{-1}).

Treatments	Yield (ton ha^{-1})
Cabbage + lettuce (T2)	50.008^{a}
Cabbage (T1)	36.975^{ab}
Cabbage + chard (T3)	34.908^{b}
Cabbage + parsley (T4)	34.208^{b}
CV (%)	24.36
LSD	0.79

Means followed by different letters in the column differ statistically according to the Tukey test at a 5% probability of error, CV=Coefficient of Variance, LSD=Least Significant Difference.

According to Hernández (2019), determining the influence of polyculture on pests and productive indicators in *Brassica oleracea* L., where estimated cabbage yields were above 60 (ton ha^{-1}) in both treatments (monoculture and association). These data were higher than those obtained in this experiment.

It can be stated that the productivity and quality of cabbage heads are influenced by several factors, including plant population, genotype, climatic conditions, water regime and soil nutritional status (Tegen and Jembere 2022). It is thus important to consider that the intercropping species should not impede the growth of the main crop, should not compete with it, and should be a species that is advantageous to the main crop. This was demonstrated in the present investigation, where the combination of cabbage and lettuce resulted in a positive yield outcome. Therefore, when considering methods of increasing yield, cultivation practices such as intercropping are the optimal choice (Turan et al. 2022).

Equatorial Diameter of Cabbage Head

The analysis of variance (ANOVA), as presented in Table 3, revealed no statistically significant differences between the treatments in the determination of the equatorial diameter of the head of cabbage using two production systems (monoculture and association). The resulting data yielded the following measurements: 18.84 cm (T1), 21.18 cm (T2), 18.15 cm (T3), and 17.50 cm (T4).

Table 3. Mean Comparison for Equatorial Head Diameter.

Treatments	Equatorial Head Diameter (cm)
Cabbage + lettuce (T2)	21.18[a]
Cabbage (T1)	18.84[a]
Cabbage + parsley (T4)	18.15[a]
Cabbage + chard (T3)	17.50[a]
CV (%)	24.36
LSD	0.79

Means followed by different letters in the column differ statistically according to the Tukey test at a 5% probability of error, CV=Coefficient of Variance, LSD=Least Significant Difference.

The fact that there were no statistical differences in cabbage head diameter based on the cropping system in this trial may be because cabbage and other leafy green vegetables have different requirements and do not compete for production factors. Head diameter is also considered to be an important component of cabbage yield.

El-Remaly et al. (2022) refer that cabbage is a relatively mid-season crop that grows slowly in the first growth phase, which provides the opportunity to intercrop a short-season crop such as lettuce with the main crop while maintaining yield and quality. Furthermore, lettuce is a short-season crop and its water and mineral requirements do not conflict with those of the main crop, cabbage. This reinforces the fact that there were no differences between the treatments applied in the present investigation.

Llomitoa et al. (2023) observed that the use of dolomite and earthworm humus in the cultivation of cabbage (*Brassica oleracea* L. var. capitata) resulted in head diameter measurements ranging from 19.70 to 22.67 cm, with an average of 20.92 cm. They found no statistical difference between these measurements, indicating that the replications within the experimental unit were properly distributed and homogeneous. These findings align with the results of the present experiment.

Polar Diameter of Cabbage Head

The ratio of the length of the polar and equatorial diameters defines the characteristic shape of the head of a given cabbage cultivar, and both dimensions also determine the weight of the cabbage head. Plant spacing is influential in any cultivation system and cultivar, mainly in cabbage cultivation (Girard and Osorio 1975). No significant differences were found regarding the effect of different planting densities on the variable polar diameter of the cabbage head (Table 4).

In a study of intercropping lettuce and broccoli, Martinez et al. (2024) observed a significant improvement in broccoli yield and suggested that to mitigate nutrient competition in intercropping systems, it is recommended to select plant species with different rooting patterns, nutrient requirements, and periods of peak nutrient demand.

Table 4. Mean Comparison for Polar Head Diameter.

Treatments	Equatorial Head Diameter (cm)
Cabbage + lettuce (T2)	19.25[a]
Cabbage + parsley (T4)	18.71[a]
Cabbage (T1)	17.69[a]
Cabbage + chard	17.48[a]
CV (%)	11.67
LSD	3.55

Means followed by different letters in the column differ statistically according to the Tukey test at a 5% probability of error, CV=Coefficient of Variance, LSD=Least Significant Difference.

In contrast to the findings of the present investigation, Mladenova and Yordanova (2023) who evaluated the effect of intercropping on cabbage growth and yield, concluded that, regardless of small differences, the intercropping option influenced the height and diameter of cabbage heads, indicating that intercropping had the most complex effect on the analyzed indicators, evidencing that when two species are intercropped, the dominant species can increase its yield and nutrient uptake, while the yield of the other crop is reduced due to interspecific competition for nutrients (Shanmugam et al. 2022).

CONCLUSION

This study highlights the importance of intercropping in improving cabbage yield and weed management. Intercropping cabbage with lettuce or chard not only reduced weed incidence, but also resulted in higher yields than monoculture, with the highest yield recorded in treatment T2 (cabbage + lettuce).

Overall, the results support the adoption of intercropping strategies to increase economic viability and promote sustainable agriculture.

It is recommended intercropping systems be implemented to specific conditions and crop combinations to maximize yields and minimize weed competition. In addition, further research should investigate the long-term effects of different intercropping strategies on pest management and soil properties to refine sustainable horticultural practices.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest for the publication of this scientific article.

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