Impact of organic mulch and exposure to shallow groundwater levels on Cnidoscolus aconitifolius in a tropical wetland, South Sumatra, Indonesia

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Impacto del mantillo orgánico y la exposición a niveles poco profundos de agua subterránea sobre *Cnidoscolus aconitifolius* en un humedal tropical, Sumatra del Sur, Indonesia

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ABSTRACT

Agricultural land in Indonesia is decreasing due to its conversion for various non-agricultural interests, which are economically more profitable. The remaining land available for agricultural activities is a suboptimal wetland. The reduction in cultivable areas has led to the evaluation of alternative crops in suboptimal land conditions. Chaya (*Cnidoscolus aconitifolius*) is a fast-growing perennial plant, its leaves are edible and rich in vitamins, minerals, and dietary fiber. However, the chaya plant has not been intensively tested for its adaptation to shallow groundwater tables in tropical lowlands. This study aimed to assess chaya's adaptability to shallow groundwater table conditions and the benefits of using organic mulch. This research consisted of two separate parts, one part was related to organic mulch benefits (planting media without watering, with organic mulch but

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not watered, and with organic mulch and watering), while the other one was related to shallow groundwater table tolerance. The study followed a randomized complete block design consisting of three replications. Results showed that chaya plants negatively responded to the shallow groundwater table conditions. Growth retardation due to shallow groundwater levels is reflected in the averages of leaf length, leaf width, leaf area, canopy diameter, and canopy area; fresh and dry weight of stem, petiole, and leaf blade; development of roots; SPAD value at 7 weeks after transplanting and it was based on visual appearance. However, despite the increase in substrate humidity due to the application of organic mulch, the effects were not significant on most of the measured morphological traits. In conclusion, chaya plants are not able to adapt to shallow groundwater levels and do not require organic mulch on the soil surface.

Keywords: Crop adaptation; groundwater table; perennial vegetable; organic mulch; swamp cultivation.

RESUMEN

El suelo agrícola en Indonesia está disminuyendo debido a la conversión para diversos intereses que son económicamente más rentables. El suelo que aún está disponible para actividades agrícolas es el humedal subóptimo. La disminución de áreas para el cultivo ha llevado a evaluar cultivos alternativos en condiciones subóptimas. La chaya (*Cnidoscolus aconitifolius*) es una planta perenne de crecimiento rápido, con hojas comestibles, ricas en vitaminas, minerales y fibra. La chaya no ha sido sometida a pruebas para determinar su adaptación al nivel freático poco profundo en tierras bajas tropicales. El objetivo fue evaluar la adaptabilidad de la chaya en condiciones de aguas subterráneas poco profundas y las ventajas del uso de mantillo orgánico. Este estudio consistió en dos partes relacionadas con: los beneficios del mantillo orgánico (medio de plantación sin riego, con mantillo orgánico pero sin riego, y con mantillo orgánico y riego) y la tolerancia al nivel freático poco profundo. Se siguió un diseño de bloques completos aleatorizados con tres repeticiones. Los resultados mostraron que las plantas de chaya respondieron negativamente a las condiciones de niveles freáticos poco profundos. El retardo en el crecimiento debido a los niveles poco profundos de agua subterránea se observó en los promedios de longitud de la hoja, ancho de la hoja, área foliar, diámetro del dosel y área del dosel; peso fresco y seco del tallo, pecíolo y lámina foliar; desarrollo de raíces; valor SPAD a las 7 semanas después del trasplante y con base en la apariencia visual. Sin embargo, a pesar del incremento en la humedad del sustrato debido a la aplicación de mantillo orgánico, los efectos no fueron significativos en la mayoría de los rasgos morfológicos medidos.

En conclusión, las plantas de chaya no son capaces de adaptarse a niveles poco profundos de agua subterránea y no requieren mantillo orgánico en la superficie del suelo.

Palabras clave: Adaptación de cultivos; nivel freático; hortaliza perenne; mantillo orgánico; cultivo palustre.

INTRODUCTION

Chaya (*Cnidoscolus aconitifolius*) is a fast-growing perennial vegetable. The consumed parts of plants are the young leaves or shoots. Leaf vegetables are a source of vitamins (Khan *et al.*, 2022; Zhang *et al.*, 2023), minerals (Dobrowolska-Iwanek *et al.*, 2022; Weyh *et al.*, 2022), and dietary fiber (Fernandes *et al.*, 2023; Plakantonaki *et al.*, 2023) that are needed for humans to be able to live healthy. In addition to these three types of nutrients, certain vegetable plants also produce phytochemicals that have positive properties for health (Sarker & Oba, 2019), including widely known antioxidants (Vazquez-Olivo *et al.*, 2023; Zeng *et al.*, 2023).

The chaya plant has been shown to adapt well to tropical climate zones (Ebel *et al.*, 2019; Gustiar *et al.*, 2023a, 2023b) with high rainfall but has not been tested for cultivation in wetlands with shallow groundwater levels that often occur during the rainy season. Conversely, during the early dry season, due to high air and soil temperatures, the land quickly dries out due to evapotranspiration activities. Efforts were made to reduce the evapotranspiration rate by covering the soil surface using organic mulch in the form of fallen leaves supplemented with controlled water supplies.

Most wetlands are classified as suboptimal lands (Bhermana *et al.*, 2021), except paddy fields equipped with technical irrigation infrastructure. Thus, the expansion of agricultural land will be faced with suboptimal land conditions, which means it requires additional efforts and costs to be productive. The heavy burden faced by farmers and the government to expand crop cultivation areas in wetland ecosystems, especially in managing water resources control systems (Stefanakis, 2019) when land is inundated in the rainy season and drought in the dry season. In addition, it is also needed to increase the pH and availability of soil macronutrients.

Lowland swamps with shallow groundwater are thought to present a suitable environment for chaya plants for development. The two studies were carried out, separately because the environmental conditions of the two studies were different, namely, one to simulate shallow water tables during rainy season conditions and the other to simulate the effects of organic mulch during dry season conditions. Therefore, this research aims to evaluate: (1) the response of chaya plants to organic mulch cover with and without regular watering, and (2) the adaptability of chaya plants to the position of the shallowest groundwater level from 11.5 cm to a depth of 17.5 cm below the surface of the growing medium.

MATERIALS AND METHODS

Experimental site and agroclimatic conditions

The research was conducted at the Jakabaring Research Facility (104°46'44''E and 3°01'35'S), South Sumatra, Indonesia. The study was conducted during the dry season. The climatic conditions at the study site were classified as lowland tropical zones with daily rainfall and relative humidity levels as shown in Fig. 1.

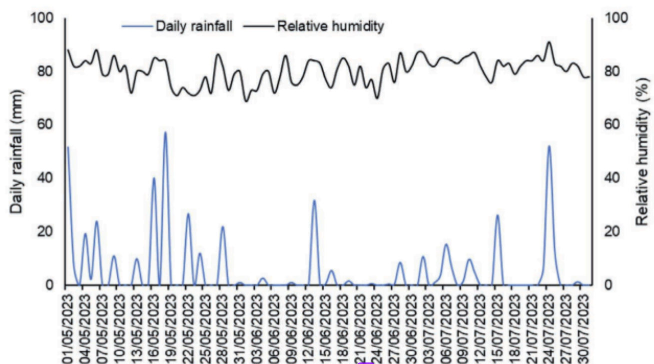


Fig. 1. The daily rainfall and relative humidity at the research site during the research had been conducted. (Source: Indonesian Agency for Meteorology, Climatology and Geophysics).

Fig. 1. Datos de las precipitaciones diarias y la humedad relativa en el área analizada (Fuente: Agencia Indonesia de Meteorología, Climatología y Geofísica).

Planting material, cultivation procedure, and treatment

Planting material is obtained from the middle part of the stem of a healthy and morphologically normal mother plant. Stem cuttings measure 25 cm long x about 2 cm in diameter. All selected planting material was further selected to obtain planting material that is as uniform as possible.

The plant is planted in pots measuring 30 cm (deep) x 30 cm (diameter) with bottom and side holes. Topsoil was poured into the pot to the brim to serve as planting substrate. Before planting, a bio fungicide solution of 2 g/liter (400 ml/pot) was applied to planting substrates that have *Streptomyces* sp., *Geobacillus* sp., and *Trichoderma* sp. Then, the planting substrate was incubated for one week.

The stem cuttings are positioned perpendicular to the top, and then the bottom part of the cuttings was pressed down into the soil medium to 5 cm deep. Moreover, the planted stem cuttings were regularly watered for maintain soil moisture.

There were two separate research units conducted, namely (1) assessing the magnitude of the benefits of using organic mulch in the cultivation of chaya plants and (2) evaluating the tolerability of chaya plants to shallow groundwater levels. The positive effect of using organic mulch on chaya cultivation is to reduce excessive rice straw buildup after the rice harvest period. The accumulated straw is generally burned by local farmers, which consequently increases carbon emissions. Meanwhile, studies on shallow groundwater levels were conducted to assess the possibility of cultivating chaya plants in wetlands with short-term flooding.

The study on the benefits of organic mulch was conducted by comparing planting media without watering (OMW-00), with organic mulch but not watered (OMW-10), and with organic mulch and watering (OMW-11). The organic mulch used was dry leaves sprinkled on the surface of the medium. The average dry leaf water content was 7.27% and applied at 100 g/pot, i.e., the soil surface was fully covered by multi-layer dry leaves. Watering was carried out every afternoon until the media reached the maximum water holding capacity, characterized by the appearance of water droplets falling in the drainage hole at the bottom of the pot. Plants that were not watered receive water naturally at level shown in Fig. 1. Meanwhile, the tolerance study to shallow groundwater table conditions was conducted by comparing planting media with groundwater table at a depth of 11.5 cm (GWL-115), 15.5 cm (GWL-155), and 17.5 cm (GWL-175) from the soil surface.

Data collection

The data collected were related to substrate conditions and chaya morphological growth. The parameter evaluated for the substrate was soil moisture. Continuous measurements of the substrate moisture were conducted both before and after treatment application. Substrate moisture was measured using a soil moisture meter (Lutron Soil Moisture Meter PMS-714). Substrate moisture measurement was carried out at 2 p.m. by stabbing the soil moisture meter sensor into the substrate at a depth of 5 cm.

In relation to chaya growth, both non-destructive and destructive observations were conducted. Non-destructive data collection was weekly, and began at 3 weeks after planting (WAP). The morphological parameters that were measured in non-destructive observations included canopy area, canopy diameter, leaf number, midrib length, leaf width, leaf length, width/length ratio, leaf area, and SPAD value. The canopy area was measured using digital scanning using the Easy Leaf Area for Android. Meanwhile, the SPAD value was measured via direct measurement using a chlorophyll meter (Chlorophyll Meter SPAD-502Plus). The destructive data were collected at 8 WAP, including fresh and dry weights of stem, bud, leaf blade, petiole, and roots.

Experimental design and statistical analysis

The study was conducted in two separate research units, namely (1) assessing the magnitude of the benefits of using organic mulch in the cultivation of chaya plants and (2) evaluating the tolerability of chaya plants to shallow groundwater levels. Each research unit used a randomized complete block design consisting of three replications. The obtained data was subjected to the analysis of variance using $p \leq 0.05$ as the least significant difference. Several parameters were investigated using simple regression to figure out their relationships. RStudio (version 2023) for Windows was used for some of the analysis. All data obtained were visualized in tables and figures.

RESULTS

Substrate condition

Measurement of soil moisture reveals the moisture content of the substrate. Chaya planted without mulch and watering (OMW-00) indicated drier substrate conditions as shown from the results of substrate moisture of the growing measurements. Greater water loss in OMW-00 is thought to be due to greater water loss through transpiration and evaporation. Conversely, organic mulch applied to OMW-10 and OMW-11 was able to reduce the evaporation process. In the case of water table, GWL-115 is the treatment with the shallowest groundwater table (Fig. 2).

Weekly chaya growth on different morphological traits

Collection of several types of data can be done non-destructively per week, including data on canopy area, canopy diameter, number of leaves, and SPAD value. The rate of leaf enlargement can be estimated based on the leaf length and width. Non-destructive measurement of leaf length and width provide chances to track the pace of leaf expansion on the same leaves with many, intensive measurements each day. If needed, it can also be done by the hour.

The canopy growth of chaya grown without groundwater table or without mulch and watering has been used as control in these studies. The size of leaf area and diameter of the canopy were not significantly affected by the application of organic mulch, either with or without watering. However, the position of groundwater table that was too shallow, for example only 11.5 cm from the upper surface of the growing medium or shallower tends to significantly inhibit the enlargement of chaya leaves, as in GWL-115 treatment. Symptoms of inhibition of leaf blade development have been seen from 3 to 8 weeks after planting (Fig. 3).

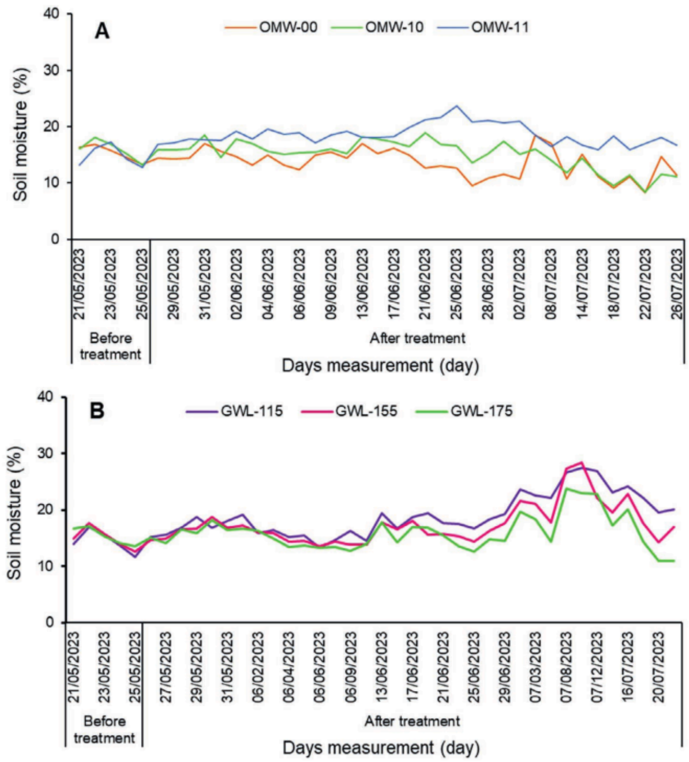


Fig. 2. Comparison of soil moisture with and without organic mulch (A) and at different depths of the groundwater table (B). OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 2. Comparación de la humedad del suelo con y sin mantillo orgánico (A) y a diferentes profundidades del nivel freático (B). OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

The low moisture content of leaves, both due to limited water supply as in the OMW-00 treatment and due to limited growing space for root development as in the GWL-115 treatment, in the short term has not significantly affected the number of leaves in the chaya plant, unless the difference in moisture content lasts consistently for 8 weeks after planting. However, the direction of tendency is different; the number of leaves is more in the mulching and watering applications, while the number of leaves is less with the presence of shallow groundwater table (Fig. 4).

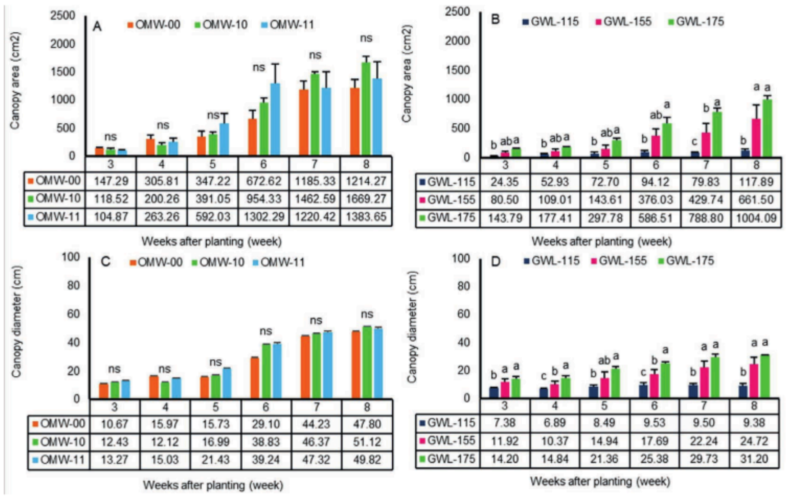


Fig. 3. Comparison of leaf area and diameter under or without organic mulch (A) and at different depths of the groundwater table (B). Each bar followed by the different letter means significantly different at $LSD_{0.05}$. Meanwhile, ns means do not significantly different at $LSD_{0.05}$. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 3. Comparación del área foliar y el diámetro bajo o sin mantillo orgánico (A) y a diferentes profundidades del nivel freático (B). Cada barra seguida de una letra diferente significa significativamente diferente a LSD0.05. Mientras tanto, ns significa no significativamente diferente a LSD0.05. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

SPAD value had often been used as a non-destructive method for determining the chlorophyll and nitrogen contents in leaves. An interesting finding from this study was that the index of leaf SPAD values was higher in plants that got reduced water supply because they were not mulched and not routinely watered (Fig. 5). Its water source depended only on rainfall. The higher value of SPAD was related to canopy area or total leaf area which was also low in plants that lack water supply. SPAD value measurements were performed on the same sensor surface area and did not depend on actual leaf area. The density of chlorophylls could be higher due to the accumulation of chlorophyll grains on smaller leaf surface, not necessarily related to actual number of chlorophylls per individual leaf. However, SPAD values were consistently lower in chaya plants treated with shallower groundwater table conditions (GWL-115).

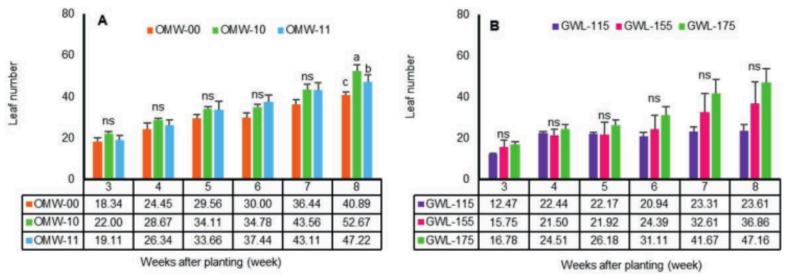


Fig. 4. Comparison of number of leaves under or without organic mulch (A) and at different depths of the groundwater table (B). The ns means do not significantly different at LSD 0.05. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 4. Comparación del número de hojas bajo o sin mantillo orgánico (A) y a diferentes profundidades del nivel freático (B). Las medias ns no difieren significativamente al LSD0.05. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

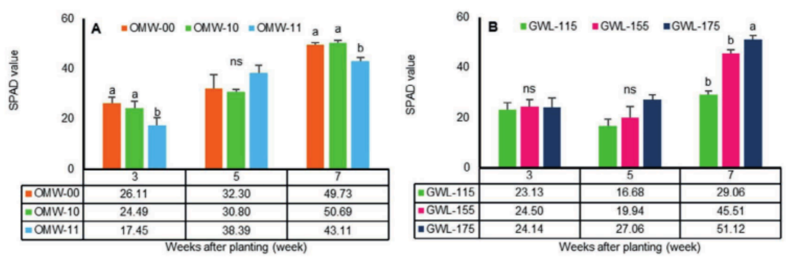


Fig. 5. Comparison of SPAD values under or without organic mulch (A) and at different depths of the groundwater table (B). Each bar followed by the different letter means significantly different at $LSD_{0.05}$. Meanwhile, ns means do not significantly different at $LSD_{0.05}$. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 5. Comparación de los valores de SPAD bajo o sin mantillo orgánico (A) y a diferentes profundidades del nivel freático (B). Cada barra seguida de una letra diferente significa significativamente diferente a LSD0.05. Mientras tanto, ns significa no significativamente diferente a LSD0.05. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

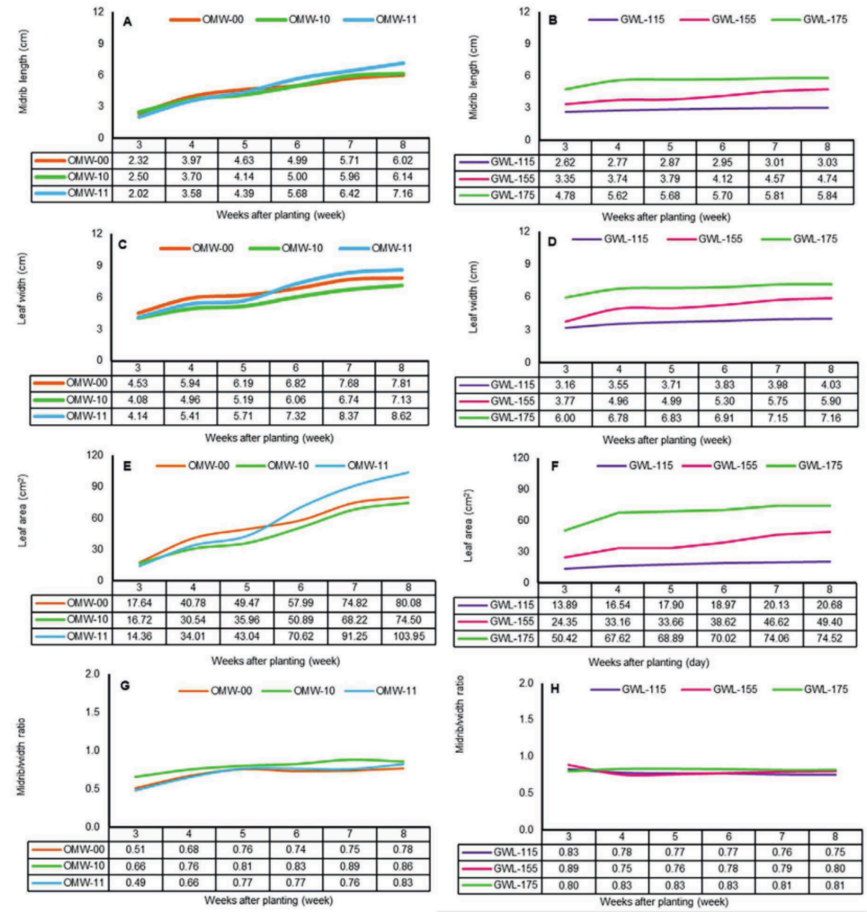
There is a tendency that midrib length and leaf width increase faster with increasing age of chaya plants that are treated with a combination of mulch application with periodic application of water. Furthermore, the bidirectional process of leaf enlargement, i.e., in the direction of leaf length or width, multiplies the difference in chaya leaf area between mulched plants plus regular water supply and non-mulched plants and water sources based solely on natural rainfall. The ratio of midrib length to leaf width was not affected by the variety of combinations of mulch treatment plus the application of watering chaya plants (Fig. 6).

Different things are seen in the treatment of the depth of the groundwater level. The midrib length, leaf blade width, and leaf area of chaya plants follow the gradation of differences in groundwater table depth, i.e., the greatest length, width, and leaf area are seen in plants exposed to the deepest groundwater table (17.5 cm) and vice versa the smallest length, width, and leaf area are seen in plants that experience the shallowest groundwater table (11.5 cm), or basically, the smallest volume of the aerobic growing media. However, the ratio between midrib length and leaf width was not different for the three differences in groundwater table depth. This indicates that the shape of the leaf is not affected by the size of the leaf blade.

Chaya plants are harvested on young shoots with green stem and still not hardened. The main part of the shoots consumed is the young leaf blades along with its petiole. The highest wet weight of leaf blades was obtained from chaya plants whose soil surface was covered with organic mulch. For plants that have been mulched, then also regularly watered, produced lower young leaf yields. This is likely due to the growing media becoming excessively moist. Plants exposed to groundwater table showed a tendency that the shallower the position of the groundwater table (11.5 cm), the lower the yield of the young leaves harvested. The total wet weight of chaya plant biomass followed the yield trend (Fig. 7).

Dry weight measurement is carried out by separating each part of the plant into roots, stems, petioles, and leaf blades. The dry weight of all plant components did not differ significantly between treatment with or without organic mulch and with or without watering. Conversely, differences in the depth of the groundwater table affected the dry weight of the stems, petioles, and leaf blades of chaya plants (Table 1).

The difference in the growth of aboveground organs in chaya plants was influenced by differences in the depth of the groundwater level. This difference is clearly visible in Fig. 8 and aligns with the data shown in Table 1. The difference in dry weight of stems, leaf blades, and petioles between plants exposed to a depth of 17.5 cm compared to those exposed at 11.5 cm was almost 10-fold for stems, more than 7-fold for leaf blades, and nearly 10-fold for petioles, respectively. As for plants exposed to groundwater levels at a depth of 15.5 cm, they were consistently in between the two extremes.



A	3	4	5	6	7	8
OMW-00	2.32	3.97	4.63	4.99	5.71	6.02
OMW-10	2.50	3.70	4.14	5.00	5.96	6.14
OMW-11	2.02	3.58	4.39	5.68	6.42	7.16

B	3	4	5	6	7	8
GWL-115	2.62	2.77	2.87	2.95	3.01	3.03
GWL-155	3.35	3.74	3.79	4.12	4.57	4.74
GWL-175	4.78	5.62	5.68	5.70	5.81	5.84

C	3	4	5	6	7	8
OMW-00	4.53	5.94	6.19	6.82	7.68	7.81
OMW-10	4.08	4.96	5.19	6.06	6.74	7.13
OMW-11	4.14	5.41	5.71	7.32	8.37	8.62

D	3	4	5	6	7	8
GWL-115	3.16	3.55	3.71	3.83	3.98	4.03
GWL-155	3.77	4.96	4.99	5.30	5.75	5.90
GWL-175	6.00	6.78	6.83	6.91	7.15	7.16

E	3	4	5	6	7	8
OMW-00	17.64	40.78	49.47	57.99	74.82	80.08
OMW-10	16.72	30.54	35.96	50.89	68.22	74.50
OMW-11	14.36	34.01	43.04	70.62	91.25	103.95

F	3	4	5	6	7	8
GWL-115	13.89	16.54	17.90	18.97	20.13	20.68
GWL-155	24.35	33.16	33.66	38.62	46.62	49.40
GWL-175	50.42	67.62	68.89	70.02	74.06	74.52

G	3	4	5	6	7	8
OMW-00	0.51	0.68	0.76	0.74	0.75	0.78
OMW-10	0.66	0.76	0.81	0.83	0.89	0.86
OMW-11	0.49	0.66	0.77	0.77	0.76	0.83

H	3	4	5	6	7	8
GWL-115	0.83	0.78	0.77	0.77	0.76	0.75
GWL-155	0.89	0.75	0.76	0.78	0.79	0.80
GWL-175	0.80	0.83	0.83	0.83	0.81	0.81

Fig. 6. Differences and similarity in the length of midrib (A, B), leaf width (C, D), leaf area (E, F), and leaf shape as shown by the ratio between midrib length and leaf width (G, H). OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 6. Diferencias y similitudes en la longitud del nervio central (A, B), la anchura de la hoja (C, D), el área foliar (E, F) y la forma de la hoja según la relación entre la longitud del nervio central y la anchura de la hoja (G, H). OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

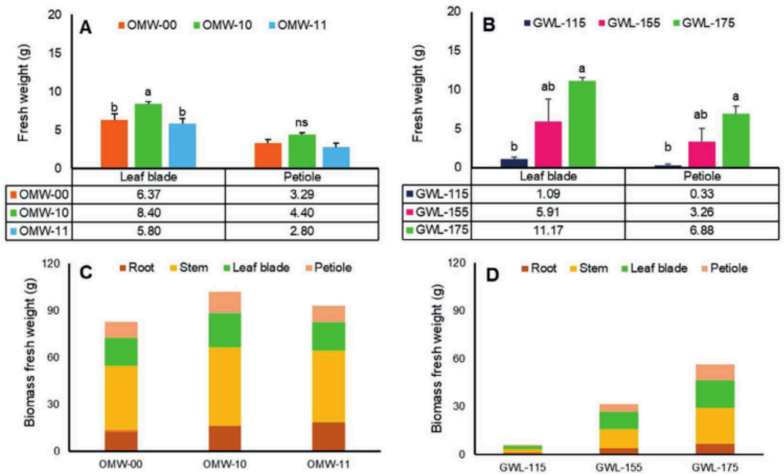


Fig. 7. The yield of edible young leaves and the total biomass of chaya plants treated with organic mulch (A) and different water table depths (B). Each bar followed by the different letter means significantly different at $LSD_{0.05}$. Meanwhile, ns means do not significantly different at $LSD_{0.05}$. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 7. El rendimiento de hojas jóvenes comestibles y la biomasa total de plantas de chaya tratadas con mantillo orgánico (A) y diferentes profundidades del nivel freático (B). Cada barra seguida de una letra diferente significa significativamente diferente a LSD0.05. Mientras tanto, ns significa no significativamente diferente a LSD0.05. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

Root development in chaya plants was carried out destructively at the age of eight weeks after the stem cuttings were planted. Root system damage in chaya plants increased as soil moisture increased (Fig. 2), especially in chaya plants whose media surface was covered with organic mulch and watered regularly (OMW-11) and in plants exposed to shallow groundwater level (GWL-115). The impact on the root system of chaya plants due to shallow groundwater level was visually more severe (GWL-115) than due to increased soil moisture and excessive water supply (OMW-11) (Fig. 9).

Table 1. The dry weight of roots, stem, petiole, and leaf blade of chaya plants treated with organic mulch (OMW) and different water table depths (GWL).

Tabla 1. Peso seco de raíces, tallo, pecíolo y lámina foliar de plantas de chaya tratadas con mantillo orgánico (OMW) y diferentes profundidades del nivel freático (GWL).

Treatments	Dry weight (g)			
	Root	Stem	Leaf blade	Petiole
OMW-00	1.59 ± 0.19 a	5.43 ± 0.95 a	3.95 ± 0.57 a	1.35 ± 0.37 a
OMW-10	2.43 ± 0.12 a	6.77 ± 0.20 a	5.06 ± 0.39 a	1.87 ± 0.13 a
OMW-11	2.25 ± 0.49 a	5.98 ± 1.49 a	4.49 ± 1.00 a	1.35 ± 0.38 a
GWL-115	0.11 ± 0.07 a	0.27 ± 0.05 b	0.54 ± 0.21 b	0.12 ± 0.02 b
GWL-155	0.46 ± 0.28 a	1.48 ± 0.85 ab	2.10 ± 0.92 b	0.57 ± 0.30 b
GWL-175	0.83 ± 0.06 a	2.65 ± 0.41 a	3.89 ± 0.16 a	1.17 ± 0.07 a

The data are presented as an average + standard error. The numbers followed by the same letter means do not significantly different using $LSD_{0.05}$ test. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Los datos se presentan como media + error estándar. Los números seguidos de la misma letra no difieren significativamente mediante la prueba $LSD_{0.05}$. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

Fig. 8. Visual comparison between chaya plants exposed to ground water level at depths of 11.5 cm, 15.5 cm, and 17.5 cm from the surface of the growing medium, respectively. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-115 = with water table at 11.5 cm, GWL-155 = water table at 15.5 cm, and GWL-175 = water table at 17.5 cm below media surface.

Fig. 8. Comparación visual entre plantas de chaya expuestas al nivel freático a profundidades de 11,5 cm, 15,5 cm y 17,5 cm desde la superficie del medio de cultivo, respectivamente. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

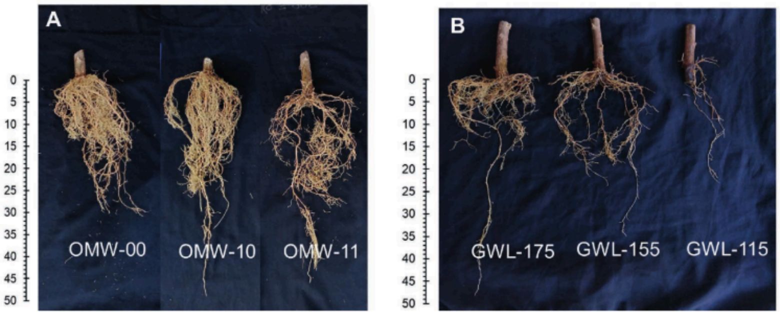


Fig. 9. The roots of chaya plants were treated with organic mulch (A) and different water table depths (B) at 8 weeks after the stem cutting was planted. OMW-00 = without mulch and watering, OMW-10 = with mulch but no watering, and MWO-11 = with mulch and watering. GWL-175 = with water table at 17.5 cm, GWL-155 = water table at 15.5 cm, and GWL-115 = water table at 11.5 cm below media surface.

Fig. 9. Las raíces de las plantas de chaya fueron tratadas con mantillo orgánico (A) y diferentes profundidades del nivel freático (B) a las 8 semanas después de plantar el esqueje. OMW-00 = sin mantillo ni riego, OMW-10 = con mantillo pero sin riego, y OMW-11 = con mantillo y riego. GWL-115 = con nivel freático a 11.5 cm, GWL-155 = nivel freático a 15.5 cm, y GWL-175 = nivel freático a 17.5 cm por debajo de la superficie del medio.

DISCUSSION

Organic mulch for retaining substrate moisture

Substrate moisture has often been used as an approach to figure out the availability of water for plants. Substrate moisture can also be used for evaluating the ability of the substrate to retain water. Thus, in some cases, substrate moisture can be used in checking the lack or excess of water in the field (Domínguez-Niño, 2020; Fang *et al.*, 2021).

Based on the results of direct measurement on substrate moisture, it was found that chaya plants grown without mulching and regular watering showed good growth; In contrast, the surface covering the growing medium using organic mulch both with and without regular watering showed slower growth. High humidity within the pore of the growing media can cause a decrease in the availability of oxygen in the growing media (Pan *et al.*, 2020). Towards the end of this study, there was a significant increase in the substrate humidity (Fig. 2).

The use of organic and synthetic mulch is intended to, among others, reduce the rate of evapotranspiration (Bogunović *et al.*, 2023). The presence of a layer of organic mulch will reduce direct exposure to sunlight so that it can maintain that the temperature on the surface of the growing media does not significantly increase (Busari *et al.*, 2023). Thus, water loss through the evaporation process will slow down. However, the transpiration process that occurs on the leaf surface through stomata will still take place because the leaves are in a higher position than the surface of the growing medium.

Water for transpiration is absorbed directly by the roots of the plant and transported to the leaves through xylem vessels.

Kader *et al.* (2019) stated that certain kinds of mulch, organic mulch included, contribute to water conservation by inhibiting evaporation-related water loss. In addition to preventing evaporation-induced water loss, organic mulch has additional benefits over plastic mulch. As stated by Liao *et al.* (2021), decomposed organic mulch increases soil porosity and improves soil physical properties. A rise in soil porosity will result in an enhancement of the soil's capacity to retain water. The study conducted by Wang *et al.* (2021) verified that substrates that are covered with a specific thickness of organic mulch exhibit a greater capacity to retain water in comparison to those that did not have organic mulch applied.

Inhibition of the evaporation process from moist soil or growing media, i.e., containing high water content, can cause losses in plant cultivation activities, especially against plant types and varieties that are intolerant to soil pore conditions filled with water or saturated with moisture. The process of root metabolism will be disrupted and the growth of the upper organs of the plant will also be inhibited in growth and development. This unexpected condition occurred in this study. This study was conducted from May to June, which is still in the mid-dry season period. Now and in the future, it is expected to be increasingly difficult to predict the right growing season for farmers (Pendergrass *et al.*, 2020; Van Klompenburg *et al.*, 2020).

Critical depth of groundwater table for chaya plant

Chaya has been recognized as a plant that can adapt well to some abiotic stresses, for example its adaptation to drought and high temperatures in tropical climate zones (Ramos & Freire, 2019), but it is not yet known whether chaya plants can also adapt to wetland conditions. At the initial stage, its adaptation to shallow groundwater table conditions is tested. Munguía-Rosas (2021) found that domesticated chayas have a water and starch storage capacity 1.1 times greater than their wild ancestors. In addition, the stems of domesticated plants produce 1.25 times more roots than wild ancestors.

The results of this study indicate that chaya plants cannot adapt to shallow groundwater table conditions. The growth of chaya plants decreases sharply if the depth of the groundwater table is shallower than 17.5 cm. Furthermore, as the chaya plant continues to grow, the groundwater table is expected to continue to deepen. It can be concluded that chaya plants are sensitive to water saturated soil pore conditions (Zhou *et al.*, 2021) or the root system of chaya plants is sensitive to hypoxic conditions (Lacroix *et al.*, 2021).

Empirical evidence showed that water availability as well as excessive water conditions occurred at the shallowest water tables position. The process of water permeating the pores was enabled by the capillary force. Water will be transported to pores and devoid of the air within the pores (Gavrilescu, 2021). As a result, the anaerobic part of the growing media would invade some of the planting media that was originally aerobic. The roots of terrestrial plants such as chaya are not equipped with aerenchyma channels needed to supply oxygen to submerged parts of the roots or in air cavities within the water-saturated rhizosphere. Oxygen deficiency negatively affects and leads to metabolic disorders in the roots (León *et al.*, 2021; Zahra *et al.*, 2021).

The volume of aerobic growing media becomes narrower if the groundwater level rises towards the upper surface of the media. The limited volume of the growing media reduces the capacity of the roots to absorb water and nutrients that are absolutely needed to support the growth of the upper part of the chaya plant. Chemical elements that are harmful or can poison plants may also be absorbed by plant roots, because these harmful elements become soluble and available. This phenomenon explains why plants become stunted when water is abundant below the soil surface (Parkash & Singh, 2020; Faridah *et al.*, 2023). Oleszczuk *et al.*, (2022) also added that the soil in a position above the groundwater table also becomes moister.

CONCLUSION

Chaya plants responded negatively to the application of organic mulch in shallow groundwater table conditions. Chaya plants are not able to adapt to shallow groundwater levels and do not require organic mulch on the soil surface. As a recommendation, the cultivation of chaya plants in wetlands should be carried out at a greater depth of groundwater table (> 30 cm) and coarse organic matter needs to be coarsely ground and mixed with the growing substrate so that soil pores increase and soil moisture decreases. Further research is needed to examine the chaya plant growth using another organic mulch under different environmental stresses.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Bhermana, A., Suparman, S., Tunisa, H. & Sunarminto, B. H. (2021). Identification of land resource potential for agricultural landscape planning using land capability evaluation approach and GIS application (a Case in Central Kalimantan Province, Indonesia). *Journal of Suboptimal Lands* 10 (2): 170-177. https://doi.org/10.36706/jlso.10.2.2021.549

Bogunović, I., Hrelja, I., Kisić, I., Dugan, I., Krevh, V., Defterdarović, J., Filipović, V., Filipović, L. & Pereira, P. (2023). Straw mulch effect on soil and water loss in different growth phases of maize sown on stagnosols in croatia. *Land* 12 (4): 765. https://doi.org/10.3390/land12040765

Busari, M. A., Bankole, G. O., Adiamo, I. A., Abiodun, R. O. & Ologunde, O. H. (2023). Influence of mulch and poultry manure application on soil temperature, evapotranspiration and water use efficiency of dry season cultivated okra. *International Soil and Water Conservation Research* 11 (2): 382-392. https://doi.org/10.1016/j.iswcr.2022.09.003

Dobrowolska-Iwanek, J., Zagrodzki, P., Galanty, A., Fołta, M., Kryczyk-Kozioł, J., Szlósarczyk, M., Rubio, P. S., de Carvalho, I. S. & Paśko, P. (2022). Determination of essential minerals and trace elements in edible sprouts from different botanical families –application of chemometric analysis. *Foods* 11 (3): 371. https://doi.org/10.3390/foods11030371

Domínguez-Niño, J. M., Oliver-Manera, J., Girona, J. & Casadesús, J. (2020). Differential irrigation scheduling by an automated algorithm of water balance tuned by capacitance-type soil moisture sensors. *Agricultural Water Management* 228: 105880. https://doi.org/10.1016/j.agwat.2019.105880

Ebel, R., de Jesús Méndez Aguilar, M., Castillo Cocom, J. A. & Kissmann, S. (2019). Genetic diversity in nutritious leafy green vegetable—chaya (*Cnidoscolus aconitifolius*). In: D. Nandwani, Bozeman (Eds.), *Genetic Diversity in Horticultural Plants. USA* (pp. 161-189). Switzerland: Springer Nature. https://doi.org/10.1007/978-3-319-96454-6_6

Fang, B., Kansara, P., Dandridge, C. & Lakshmi, V. (2021). Drought monitoring using high spatial resolution soil moisture data over Australia in 2015–2019. *Journal of Hydrology* 594: 125960.

Faridah, S. N., Mubarak, H., Jamaluddin, T. A. A. & Samsuar, S. (2023). Morphology and physiology of kale plants under excess and deficient water conditions. *International Journal of Vegetable Science*: 1-8. https://doi.org/10.1016/j.jhydrol.2021.125960

Fernandes, A., Mateus, N. & de Freitas, V. (2023). Polyphenol-Dietary fiber conjugates from fruits and vegetables: Nature and biological fate in a food and nutrition perspective. *Foods* 12 (5): 1052. https://doi.org/10.3390/foods12051052

Gavrilescu, M. (2021). Water, soil, and plants interactions in a threatened environment. *Water* 13 (19): 2746. https://doi.org/10.3390/w13192746

Gustiar, F., Lakitan, B., Budianta, D. & Negara, Z. P. (2023a). Assessing the impact on growth and yield in different varieties of chili pepper (*Capsicum frutescens*) intercropped with chaya (*Cnidoscolus aconitifolius*). *Biodiversitas Journal of Biological Diversity* 24 (5): 2639-2646. https://doi.org/10.13057/biodiv/d240516

Gustiar, F., Lakitan, B., Budianta, D., & Negara, Z. P. (2023b). Non-destructive model for estimating leaf area and growth of Cnidoscolus aconitifolius cultivated using different stem diameter of the semi hardwood cuttings. *Agrivita Journal of Agricultural Science* 45 (2): 188-198. http://doi.org/10.17503/agrivita.v45i2.3849

Kader, M. A., Singha, A., Begum, M. A., Jewel, A., Khan, F. H. & Khan, N. I. (2019). Mulching as water-saving technique in dryland agriculture. *Bulletin of the National Research Center* 43 (1): 1-6. https://doi.org/10.1186/s42269-019-0186-7

Khan, M. U., Gautam, G., Jan, B., Zahiruddin, S., Parveen, R. & Ahmad, S. (2022). Vitamin D from vegetable VV sources: hope for the future. *Phytomedicine Plus* 2 (2): 100248. https://doi.org/10.1016/j.phyplu.2022.100248

Lacroix, E. M., Rossi, R. J., Bossio, D. & Fendorf, S. (2021). Effects of moisture and physical disturbance on pore-scale oxygen content and anaerobic metabolisms in upland soils. *Science of the Total Environment* 780: 146572. https://doi.org/10.1016/j.scitotenv.2021.146572

León, J., Castillo, M. C. & Gayubas, B. (2021). The hypoxia–reoxygenation stress in plants. *Journal of Experimental Botany* 72 (16): 5841-5856. https://doi.org/10.1093/jxb/eraa591

Liao, Y., Cao, H. X., Liu, X., Li, H. T., Hu, Q. Y. & Xue, W. K. (2021). By increasing infiltration and reducing evaporation, mulching can improve the soil water environment and apple yield of orchards in semiarid areas. *Agricultural Water Management* 25: 106936. https://doi.org/10.1016/j.agwat.2021.106936

Munguía-Rosas, M. A. (2021). Artificial selection optimizes clonality in chaya (*Cnidoscolus aconitifolius*). *Scientific Reports* 11 (1): 21017. https://doi.org/10.1038/s41598-021-00592-0

Oleszczuk, R., Jadczyszyn, J., Gnatowski, T. & Brandyk, A. (2022). Variation of moisture and soil water retention in a lowland area of central Poland-solec site case study. *Atmosphere* 13 (9): 1372. https://doi.org/10.3390/atmos13091372

Pan, Y., Cieraad, E., Clarkson, B. R., Colmer, T. D., Pedersen, O., Visser, E. J., Voesenek, L. A. C. J. & van Bodegom, P. M. (2020). Drivers of plant traits that allow survival in wetlands. *Functional Ecology* 34 (5): 956-967. https://doi.org/10.1111/1365-2435.13541

Parkash, V. & Singh, S. (2020). A review on potential plant-based water stress indicators for vegetable crops. *Sustainability* 12 (10): 3945. https://doi.org/10.3390/su12103945

Pendergrass, A. G., Meehl, G. A., Pulwarty, R., Hobbins, M., Hoell, A., AghaKouchak, A., Bonfils, C. J. W., Gallant, A. J. E., Hoerling, M., Hoffmann, D., Kaatz, L., Lehner, F., Llewellyn, D., Mote, P., Neale, R. B., Overpeck, J. T., Sheffield, A., Stahl, K., Svoboda, M., Wheeler, M. C., Wood, A. W. & Woodhouse, C. A. (2020). Flash droughts present a new challenge for subseasonal-to-seasonal prediction. *Nature Climate Change* 10 (3): 191-199. https://doi.org/10.1038/s41558-020-0709-0

Plakantonaki, S., Roussis, I., Bilalis, D. & Priniotakis, G. (2023). Dietary fiber from plant-based food wastes: A comprehensive approach to cereal, fruit, and vegetable waste valorization. *Processes* 11 (5): 1580. https://doi.org/10.3390/pr11051580

Ramos, F. R. & Freire, A. L. O. (2019). Physiological responses to drought of *Cnidoscolus quercifolius* Pohl in semi-arid conditions. *Advances in Forestry Science* 6 (1): 493-499. https://doi.org/10.34062/afs.v6i1.5735

Sarker, U. & Oba, S. (2019). Protein, dietary fiber, minerals, antioxidant pigments and phytochemicals, and antioxidant activity in selected red morph Amaranthus leafy vegetable. *PLoS One* 14 (12): e0222517. https://doi.org/10.1371/journal.pone.0222517

Stefanakis, A. I. (2019). The role of constructed wetlands as green infrastructure for sustainable urban water management. *Sustainability* 11 (24): 6981. https://doi.org/10.3390/su11246981

Van Klompenburg, T., Kassahun, A. & Catal, C. (2020). Crop yield prediction using machine learning: A systematic literature review. *Computers and Electronics in Agriculture* 177: 105709. https://doi.org/10.1016/j.compag.2020.105709

Vazquez-Olivo, G., Cota-Pérez, J. L., García-Carrasco, M., Zamudio-Sosa, V. E. & Heredia, J. B. (2023). Antioxidant phenolics from vegetable by-products. In: R. Lone, S. Khan, A. Mohammed Al-Sadi (Eds.), *Plant Phenolics in Abiotic Stress Management*. (pp. 89-104). Singapore: Springer. https://doi.org/10.1007/978-981-19-6426-8_5

Wang, B., Niu, J., Berndtsson, R., Zhang, L., Chen, X., Li, X. & Zhu, Z. (2021). Efficient organic mulch thickness for soil and water conservation in urban areas. *Scientific Reports* 11 (1): 6259. https://doi.org/10.1038/s41598-021-85343-x

Weyh, C., Krüger, K., Peeling, P. & Castell, L. (2022). The role of minerals in the optimal functioning of the immune system. *Nutrients* 14 (3): 644. https://doi.org/10.3390/nu14030644

Zahra, N., Hafeez, M. B., Shaukat, K., Wahid, A., Hussain, S., Naseer, R., Raza, A., Iqbal, S. & Farooq, M. (2021). Hypoxia and anoxia stress: Plant responses and tolerance mechanisms. *Journal of Agronomy and Crop Science* 207 (2): 249-284. https://doi.org/10.1111/jac.12471

Zeng, Y., Zhou, W., Yu, J., Zhao, L., Wang, K., Hu, Z. & Liu, X. (2023). By-Products of fruit and vegetables: Antioxidant properties of extractable and non-extractable phenolic compounds. *Antioxidants* 12 (2): 418. https://doi.org/10.3390/antiox12020418

Zhang, Y., Yang, S., Wu, Q., Ye, Z., Zhou, C., Liu, M., Zhang, Z., He, P., Zhang, Y., Li, H., Li, R., Gan, X., Liu, C. & Qin, X. (2023). Dietary vitamin E intake and new-onset hypertension. *Hypertension Research* 46 (5): 1267-1275. https://doi.org/10.1038/s41440-022-01163-0

Zhou, H., Whalley, W. R., Hawkesford, M. J., Ashton, R. W., Atkinson, B., Atkinson, J. A., Sturrock, C. J., Bennett, M. J. & Mooney, S. J. (2021). The interaction between wheat roots and soil pores in structured field soil. *Journal of Experimental Botany* 72 (2): 747-756. https://doi.org/10.1093/jxb/eraa475

Impact of organic mulch and exposure to shallow groundwater levels on Cnidoscolus aconitifolius in a tropical wetland, South Sumatra, Indonesia

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