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WEED CONTROL IN TOMATO CROP USING ALLELOPATHIC SPECIES UNDER CONVENTIONAL AND ECOLOGICAL SYSTEMS

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Abstract

The aim of this study was to evaluate the allelopathic influence of white clover (Trifolium repens), barley (Hordeum vulgare), and oat (Avena sativa) on weed control in tomato crops. Two experimental factors were analyzed: (1) the impact of plant species with allelopathic potential on weed infestation and (2) the effects of organic versus conventional fertilization on plant development. Allelopathic species were sown simultaneously with tomato planting, using the determinate tomato (Solanum lycopersicum) cultivar 'Bacuni'. The main weed species identified were redroot pigweed (Amaranthus retroflexus), lamb's quarters (Chenopodium album), gallant soldier (Galinsoga parviflora), pale persicaria (Persicaria lapathifolia), purslane (Portulaca oleracea), field bindweed (Convolvulus arvensis), cockspur (Echinochloa crus-galli), and green foxtail (Setaria viridis). The allelopathic plants significantly reduced both the number and total biomass of weeds before the first mowing, regardless of whether the cultivation system was organic or conventional. Weed biomass increased substantially before the second tillage/mowing in all treatments, highlighting the need for continuous weed management to prevent competition with the crop. Regarding tomato production, superior results were obtained under the conventionally fertilized treatment compared to the organically fertilized one.

Key words*: sustainable agriculture, weed management, tomato production, organic fertilization.*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops in the Solanaceae family worldwide (Picanço et al., 2007) and holds significant economic importance globally (Dewapriya et al., 2024; Avasiloaiei et al., 2025). Conventional tomato cultivation practices involving excessive nitrogen fertilization degrade soil and water quality by promoting soil erosion, accelerating organic matter mineralization, and increasing NO_3^- concentrations in both surface and groundwater. Consequently, the adoption of sustainable practices is essential to maintain tomato yield while improving soil and water quality. There are some challenges in implementing reduced-tillage technologies in organic farming, particularly due to ineffective weed control and suboptimal nutrient management (Antichi et al., 2019; Abou Chehade et al., 2023). Therefore, it is crucial to identify cover crop species that can address these two issues while sustaining crop yield (Vincent-Caboud et al., 2017). Cover crops can modify soil properties, thereby influencing fruit yield and the growth of both above- and belowground tomato biomass, which are closely associated with root development (Sainju et al., 2001).

An international meta-analysis revealed that intercropping strategies, including living mulch, relay cropping, or synchronous planting of cover crops, can suppress weed populations by up to 82% compared with non-weeded control plots (Verret et al., 2017). This evidence underlines why, in the context of increasing concerns over herbicide-resistant weeds and the limited availability of new modes of action, many producers have adopted annual cover crops as a management strategy (Basinger & Hill, 2021). For instance, Grant

and Sallans (1964) demonstrated that white clover (*Trifolium repens*), extracts can inhibit the germination of various legumes and grasses. Clover plants, as reported by Taiz and Zeiger (2013), contain flavonoids and other bioactive compounds that exhibit significant biological and allelopathic effects. Once incorporated into the soil, white clover contributes to the suppression of phytoparasitic nematode populations (Carlsen & Fomsgaard, 2008) and simultaneously enhances soil fertility by providing organic matter and biologically fixed nitrogen (Hill et al., 2021). Baghestani et al. (1999) reported that barley germplasm contains a broader spectrum of allelochemicals, including phenolic acids, compared with wheat, emphasizing its value as a model crop for allelopathy research. Plant residues (Gubbels and Kenaschuk, 1989), seeds (Liu and Lovett, 1993), and root exudates (Bertholdsson, 2004; Bouhaouel et al., 2015) of barley (*Hordeum vulgare*) have also been investigated for their allelopathic potential against various crop and weed species, further supporting the species' well-recognized production of bioactive allelochemicals. According to Kato-Noguchi et al. (1994), in oats (*Avena sativa*), L-tryptophan may function as an allelochemical, affecting the germination and growth of a range of plant species.

The aim of the present study was to evaluate the effects of white clover, barley, and oat on tomato crop growth and weed control, and to assess the impact of organic versus conventional fertilization on tomato development.

MATERIALS AND METHODS

The study was conducted at the Vegetable Research and Development Station Bacău (VRDS), during the 2025 growing season and focused on the cultivation of determinate tomato varieties under both organic and conventional farming systems. The tomato cultivar 'Bacuni', patented by the VRDS Bacău, was used in the experiment. The allelopathic species investigated were white clover (*Trifolium repens*), barley (*Hordeum vulgare*), and oat (*Avena sativa*). The allelopathic species were sown simultaneously with the tomato planting. Barley and oat served as support crops to facilitate white clover establishment during germination. The spacing between rows was 140 cm, while the spacing between plants within the row was 15 cm.

In this study, two experimental factors were analyzed: (1) the influence of allelopathic potential species on tomato crops and weeds, and (2) the effects of organic and conventional fertilization on tomato crop development (Table 1).

Table 1. Variants used in the study

Variant	Allelopathic species	Main crop	Fertilization
V1F1	White clover (12 kg/ha), barley (30 kg/ha), oat (30 kg/ha)	Tomato	Organic (1 & 2: Orgevit; 3: Crop Max; 4: Etamin; 5: Crop Max + Etamin)
V1 F2	White clover (12 kg/ha), barley (30 kg/ha), oat (30 kg/ha)	Tomato	Conventional (1 & 2: NPK 15-15-15; 3: Albit; 4: Albit + Vegenergy; 5: Albit + Final K)
V2 F1	Without allelopathic species	Tomato	Organic (1 & 2: Orgevit; 3: Crop Max; 4: Etamin; 5: Crop Max + Etamin)
V2 F2	Without allelopathic species	Tomato	Conventional (1 & 2: NPK 15-15-15; 3: Albit; 4: Albit + Vegenergy; 5: Albit + Final K)

Mowing was performed twice using a garden strimmer, while the controls were tilled manually twice and once mechanically.

The fertilization treatments included the following products and application rates: Orgevit, an organic fertilizer applied at 1-1.5 t/ha; Crop Max, a natural foliar growth stimulator applied by dissolving 10 mL of product in 10 L of water; Etamin, an ecological biostimulator containing microelements and L-amino acids, applied at 0.3 L per 100 L of water; Albit, an ecological biostimulator used to enhance plant immunity and growth; Vegenergy, an organic fertilizer for advanced nutrition and physiological protection, applied at 20-25 mL per 10 L of water; Final K, applied at 3-5 L/ha; and NPK, applied at 300-400 kg/ha.

A metric frame was used to evaluate weed presence. The fresh biomass and weed density per m² were recorded. Identification of weed species was performed using a weed descriptor (Gurău, 2007). Weed infestation was assessed at two intervals: A - before the first tillage/ mowing, B - before the second tillage/mowing.

Chlorophyll and anthocyanin levels were measured using an OPTI-SCIENCES Chlorophyll Content Meter and an OPTI-SCIENCES Anthocyanin Content Meter. For each replicate, leaves for all measurements were randomly collected from three plants.

Total soluble solids concentration was determined using a high-precision handheld portable refractometer. The analysis was performed on homogenized juice obtained by pressing fresh fruits, and the results are expressed in Brix, according to method 932.12 (AOAC, 2005; Brezeanu et al., 2022). Fresh fruits were randomly sampled from three plants within each replicate. At harvest, total seed yield (t/ha) was also recorded.

Statistical analyses were performed using ANOVA, and mean comparisons were conducted with Tukey's HSD test at a significance level of $P < 0.05$ and the Bonferroni test, using IBM SPSS Statistics 20.

RESULTS AND DISCUSSIONS

In the tomato crop, several weed species were identified. The annual dicotyledonous weeds included redroot pigweed (*Amaranthus retroflexus*), lamb's quarters (*Chenopodium album*), gallant soldier (*Galinsoga parviflora*), pale persicaria (*Persicaria lapathifolia*), and purslane (*Portulaca oleracea*). The perennial dicotyledonous weeds were represented by field bindweed (*Convolvulus arvensis*). Among the annual monocotyledonous weeds, cockspur (*Echinochloa crus-galli*) and green foxtail (*Setaria viridis*) were identified. Allelopathic plants significantly reduced both weed density and total weed biomass prior to the first mowing, regardless of whether the cropping system was organic or conventional (Table 2). After mowing, in the absence of barley and oats, which provided rapid soil cover and facilitated the establishment of white clover, a pronounced increase in weed abundance was observed. This response was attributed to the poor germination and slow growth rate of white clover, which limited its ability to compete effectively with weeds. Meteorological conditions during the period immediately following sowing play a decisive role in the successful establishment of white clover, as they may lead to uneven germination and slow early growth, thereby reducing the plant's capacity to develop adequately and to compete effectively with weeds.

Table 2. Total number of weeds per m²
in the tomato crop: A - before the first tillage/mowing, B - before the second tillage/mowing

Variant	Number of weeds m²	
	A	B
V1F1	86.67±14.43 b	38.67±4.16
V1F2	80.67±21.03 b	40.67±9.24
V2F1	312.67±6.43 a	49.3±4.16
V2F2	292±27.87 a	50.33±4.62
Sig.	*	ns

V1F1 – tomatoes grown under an organic farming system with white clover, barley, and oats; V1F2 – tomatoes grown under a conventional farming system with white clover, barley, and oats; V2F1 – tomatoes grown under an organic farming system; V2F2 – tomatoes grown under a conventional farming system. Results are expressed as means ± standard deviation (SD). Different letters indicate significant differences among treatments, as determined by Tukey's post hoc test ($P < 0.05$): a – highest value recorded for the test performed; *– significant differences; ns – non-significant differences.

Weed biomass increased substantially at time B (before the second tillage/mowing) across all experimental treatments, highlighting the need for continuous weed management to prevent competition with the main crop (Table 3).

Table 3. Total fresh weed biomass g/m² in the tomato crop: A - before the first tillage/mowing, B - before the second tillage/mowing

Variant	Fresh weed biomass g/m²	
	A	B
V1F1	97±12.17 b	495.67±29.57
V1F2	101±23.30 b	488.67±22.14
V2F1	268.67±5.51 a	423±58.21
V2F2	259.67±5.03 a	444.67±26.95
Sig.	*	ns

V1F1 – tomatoes grown under an organic farming system with white clover, barley, and oats; V1F2 – tomatoes grown under a conventional farming system with white clover, barley, and oats; V2F1 – tomatoes grown under an organic farming system; V2F2 – tomatoes grown under a conventional farming system. Results are expressed as means ± standard deviation (SD). Different letters indicate significant differences among treatments, as determined by Tukey's post hoc test ($P < 0.05$): a – highest value recorded for the test performed; *– significant differences; ns – non-significant differences.

The main effect of the cropping (allelopathic species vs. tillage) system was not statistically significant ($F = 4.704$, $p = 0.062$), although the effect size was moderate ($\eta^2p = 0.370$). This trend suggests that, in the absence of

conventional fertilization, the differences between cropping systems are not sufficiently large to produce a statistically consistent yield response. The fertilization treatment had a significant effect on tomato yield (F = 27.783, p = 0.001), with a very large effect size (η^2p = 0.776). The mean yield obtained under the conventional fertilization regime (F2: 107.59) was significantly higher than that recorded under the organic fertilization regime (F1: 64.54), with a difference of 43.05 units (p = 0.001, Bonferroni test). This result confirms the decisive role of fertilization in determining yield levels (Table 4).

Table 4. Tomato yield and fruit morphological characteristics

Variant	Tomato yield (t/ha)	Fruit diameter (mm)	Fruit height (mm)
V1F1	60.88±9.66b	69.06±1.12	41.66±1.19
V1F2	93.53±5.93ab	68.63±1.08	42.10±1.58
V2F1	68.20±6.98b	66.11±2.64	43.523±1.10
V2F2	121.65±9.46a	76.98±4.68	46.78±0.71
Sig.	*	ns	ns
F1	64.54±5.58	67.58±1.44	42.59±0.83
F2	107.59±8.03	72.80±2.85	44.44±1.30
Sig.	*	ns	ns
V1	77.21±8.89	68.84±0.70	41.88±0.89
V2	94.92±13.06	71.55±3.42	45.15±0.94
Sig.	ns	ns	ns

V1F1 – tomatoes grown under an organic farming system with white clover, barley, and oats; V1F2 – tomatoes grown under a conventional farming system with white clover, barley, and oats; V2F1 – tomatoes grown under an organic farming system; V2F2 – tomatoes grown under a conventional farming system. Results are expressed as means ± Std. Error. Different letters indicate significant differences among treatments, as determined by Tukey's post hoc test (P < 0.05): a – highest value recorded for the test performed; * – significant differences; ns – non-significant differences.

The interaction between cropping system and fertilization was not statistically significant (F = 1.621, p = 0.239), indicating that the effect of fertilization is consistent across both cropping systems. In other words, conventional fertilization increases yield regardless of whether tomatoes are grown under organic or conventional cropping systems.

Regarding chlorophyll content in tomato leaves, the highest value before the first tillage/mowing (A) was recorded in V2F2 (53.23±1.9 a), which was significantly higher than V1F1 (34.73±10.42 b), V1F2 and V2F1 presented intermediate values without significant differences between them. At the second measurement (B), no significant differences were observed among the variants, indicating that the initial differences in chlorophyll content diminished over time (Figure 1).

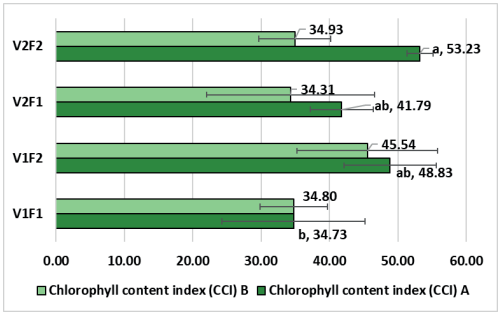

Figure 1. Chlorophyll content index in tomato leaves:
A - before the first tillage/mowing,
B - before the second tillage/mowing

Regarding anthocyanin content, no statistically significant differences were detected among the treatments at any of the evaluated time points (Figure 2).

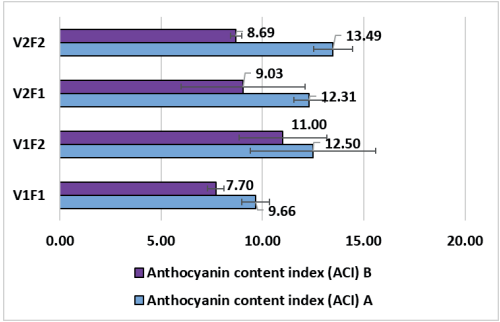

Figure 2. Anthocyanin content index in tomato leaves:
A - before the first tillage/mowing,
B - before the second tillage/mowing

Plant height before the first tillage/mowing (A) was greatest in V1F2 and V2F2, reaching approximately 31 cm, and was significantly higher than in V1F1 (27.22 cm) and V2F1 (23.56 cm) (Figures 3, 4).



Figure 3. Tomato plants cultivated with white clover, barley, and oats

At the second measurement (B), the tallest plants were observed in V2F2 and V2F1 (around 59 cm), followed by V1F2 (55.89 cm) and V1F1 (44.55 cm), with significant differrences especially between V1F1 and the other variants.

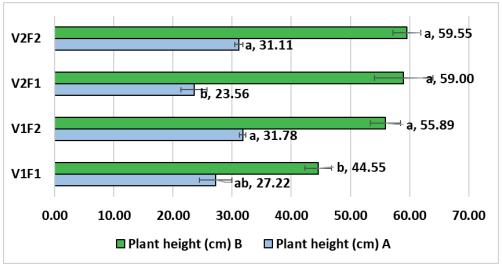

Figure 4. Plant height of tomato plants:
A - before the first tillage/mowing,
B - before the second tillage/mowing

A moderate positive correlation was observed between plant height and yield. However, the correlation was not strong, indicating that plant height is not the sole determinant of yield. Taller plants tended to produce higher yields, but yield is also influenced by other agronomic and physiological factors, such as nutrition, cropping system, competition, and abiotic stresses (Figure 5).

Linear regression analysis between tomato yield (t/ha) and weed biomass (g/m²) revealed a very weak negative relationship, with a coefficient of determination of $R^2 = 0.008$. Weed biomass accounted for only 0.8% of the total variation in yield, indicating the absence of a statistically meaningful correlation. Under the given experimental conditions, yield performance was predominantly influenced by the fertilization system, whereas weed competition did not exert a relevant effect on tomato productivity (Figure 6).

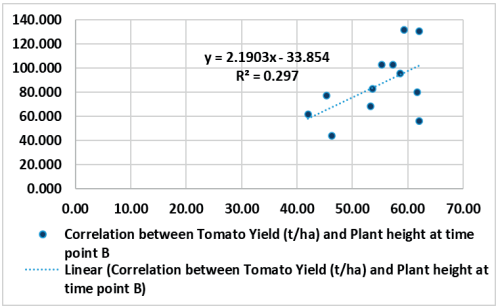

Figure 5. Correlation between tomato yield (t/ha) and plant height at time point B (before the second tillage/mowing)

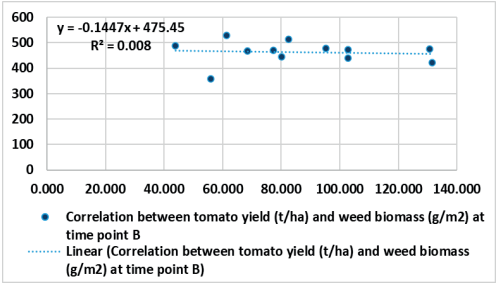

Figure 6. Correlation between tomato yield (t/ha) and weed biomass (g/m^2) at time point B (before the second tillage/mowing)

Statistical analysis revealed significant differences among treatments regarding soluble solids content ($P < 0.05$). The highest TSS value was recorded in treatment V1F2 (5.48 ± 0.19 °Brix), which was significantly higher than those observed in treatments V1F1, V2F1, and V2F2, among which no significant differences were detected (Figure 7).

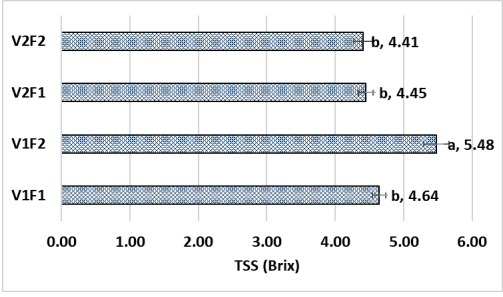

Figure 7. Total Soluble Solids (TSS, °Brix) in tomato fruits

Overall, the results demonstrate that fertilization optimization has a much more pronounced impact on tomato yield than the choice of cropping system, emphasizing the importance of nutrient management in achieving high and stable production levels.

CONCLUSIONS

Allelopathic plants (white clover, barley, and oats) significantly reduced weed density and total weed biomass prior to the first mowing; however, weed biomass increased substantially before the second management operation, highlighting the need for continuous weed management to prevent competition with the main crop.

The cropping system did not exert a statistically significant effect on most physiological traits, such as chlorophyll and anthocyanin content; however, it significantly influenced plant height, with the highest values recorded under conventional variants, particularly at sampling time B, indicating more intensive vegetative growth during the second part of the growing season.

Conventional fertilization resulted in a substantial increase in tomato yield compared to organic fertilization, confirming the essential role of nutrient supply in determining the productive performance of the tomato crop.

The cropping system, analyzed as a main effect, did not significantly influence tomato yield, although the relatively high effect size suggests a moderate biological trend. This observation indicates that differences between organic and conventional systems, in the absence of intensive fertilization, are not sufficient to generate statistically consistent yield variations.

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REFERENCES

Abou Chehade, L., Antichi, D., Frasconi, C., Sbrana, M., Tramacere, L.G., Mazzoncini, M., Peruzzi, A. (2023) Legume Cover Crop Alleviates the Negative Impact of No-Till on Tomato Productivity in a Mediterranean Organic Cropping System. *Agronomy*, *13*(8) https://doi.org/10.3390/agronomy13082027

Antichi, D., Sbrana, M., Martelloni, L., Abou Chehade, L., Fontanelli, M., Raffaelli, M., Mazzoncini, M., Peruzzi, A., Frasconi, C. (2019) Agronomic Performances of Organic Field Vegetables Managed with Conservation Agriculture Techniques: A Study from Central Italy. *Agronomy*, *9*, 810. https://doi.org/10.3390/agronomy9120810

Avasiloaiei, D. I., Calara, M., Brezeanu, P. M., Bălăiță, C., Brumă, I., S., & Brezeanu, C. (2025). Optimizing Tomato Yield and Quality in Greenhouse Cultivation Through Fertilization and Soil Management. *Agronomy*, 15(9), 2045, https://doi.org/10.3390/agronomy15092045

Baghestani, A., Lemieux, C., Leroux, G.D., Baziramakenga, R. (1999). Determination of allelochemicals in spring cereal cultivars of different competitiveness. *Weed Science*, *47*, 498–504 https://doi.org/10.1017/S0043174500092171

Basinger, N., T., & Hill, N. S. (2021). Establishing white clover (*Trifolium repens*) as a living mulch: weed control and herbicide tolerance. *Weed Technology*, *35*(5), 845-855.DOI: https://doi.org/10.1017/wet.2021.45

Bertholdsson, NO. (2004). Variation in allelopathic activity over 100 years of barley selection and breeding. *Weed Research*, *44*, 78–86 https://doi.org/10.1111/j.1365-3180.2003.00375.x

Bouhaouel, I., Gfeller, A., Fauconnier, ML. et al. (2015). Allelopathic and autotoxicity effects of barley (*Hordeum vulgare* L. ssp. *vulgare*) root exudates. *BioControl*, *60*, 425–436 https://doi.org/10.1007/s10526-014-9634-3

Brezeanu, P. M., Brezeanu, C., Tremurici, A., A., Ambăruș, S., & Bute, A. (2022). Effects of Organic Inputs Application on Yield And Qualitative Parameters of tomatoes and peppers. *Scientific Papers. Series B. Horticulture*, *66*(1).

Carlsen, S.,, C., & Fomsgaard, I. S. (2008). Biologically active secondary metabolites in white clover (*Trifolium repens* L.) - a review focusing on contents in the plant, plant-pest interactions and transformation. *Chemoecology*, *18*(3), 129-170. DOI: 10.1007/s00049-008-0402-7

Dewapriya, I.N.S., Hettiarachchi, M.H.S.M., Weerakoddy, W.A.P., Bandaranayake, A.U., Amaratunga, K.S.P., and Bandaranayake, P.C.G., (2024). Assessment of growth and yield characteristics of a greenhouse hybrid and a dual-Purpose Tomato Cultivar under Different Microclimatic Conditions. *Tropical Agricultural Research*, *35*(4), 317-331. DOI: 10.4038/tar.v35i4.8845

Grant, E.,, A., Sallens, W. G. (1954). Influence of plant extracts on germination and growth of eight forage species. *Journal of the British Grasslands Society*, *19*, 191-197.

Gubbels, G.H., Kenaschuk, E.O. (1989). Agronomic performance of flax grown on canola, barley and flax stubble with and without tillage prior to seeding. *Canadian Journal of Plant Science*, *69*, 31–38 https://doi.org/10.4141/cjps89-005

Gurău M. (2007). *Botanică sistematică*. Editura Alma Mater, Bacău, pp. 212-213.

Hill, N., S., Levi, M., Basinger, N., Thompson, A., Cabrera, M., Wallace, J., ... & Mullican, J. (2021). White clover living mulch enhances soil health vs. annual cover crops. *Agronomy Journal*, *113*(4), 3697-3707.https://doi.org/10.1002/agj2.20768Kato-Noguchi, H., Kosemura, S., Yamamura, S. et al. Allelopathy of oats. I. (1994). Assessment of allelopathic potential of extract of oat shoots and identification of an allelochemical. *Journal of Chemical Ecology*, *20*, 309–314. https://doi.org/10.1007/BF02064439

Liu, DL., Lovett, J.V. (1993). Biologically active secondary metabolites of barley. I. Developing techniques and assessing allelopathy in barley. *Journal of Chemical Ecology, 19*, 2217–2230 https://doi.org/10.1007/BF00979659

Picanço, MC., Bacci, L., Crespo, ALB., Miranda, MMM., Martins, C. (2007). Effect of integrated pest management practices on tomato production and conservation of natural enemies. *Agricultural and Forest Entomology, 9*, 327–335 https://doi.org/10.1111/j.1461-9563.2007.00346.x

Sainju, U., M., Singh, B. P., & Whitehead, W. F. (2001). Comparison of the effects of cover crops and nitrogen fertilization on tomato yield, root growth, and soil properties. *Scientia Horticulturae*, *91*(3-4), 201-214. https://doi.org/10.1016/S0304-4238(01)00264-3

Taiz, L. and Zeiger, E. (2013). *Plant Physiology*. Translate: Divan Junior et al., Artmed, Porto Alegre, 918.

Verret, V., Gardarin, A., Pelzer, E., Médiène, S., Makowski, D., Valantin-Morison, M. (2017). Can legume companion plants control weeds without decreasing crop yield? A meta-analysis. *Crop Research*, *204*, 158–168 DOI: 10.1016/j.fcr.2017.01.010

Vincent-Caboud, L., Peigné, J., Casagrande, M., Silva, E.M. (2017). Overview of Organic Cover Crop-Based No-Tillage Technique in Europe: Farmers' Practices and Research Challenges. *Agronomy*, *7*, 42. https://doi.org/10.3390/agriculture7050042

***AOAC (2005). Official Methods of Analysis of AOAC International, 21st ed.; AOAC: Gaithersburg, MD, USA