Research Article
Antioxidant Activity and Total Phenolic and Flavonoid Content of Various Solvent Extracts from In Vivo and In Vitro Grown Trifolium pratense L. (Red Clover)

Arash Khorasani Esmaeili, Rosna Mat Taha, Sadegh Mohajer, and Behrooz Banisalam

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia

Correspondence should be addressed to Arash Khorasani Esmaeili; arash_khorasani@yahoo.com

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In the present study the extracts of in vivo and in vitro grown plants as well as callus tissue of red clover were tested for their antioxidant activities, using different extraction solvent and different antioxidant assays. The total flavonoid and phenolic contents as well as extraction yield of the extracts were also investigated to determine their correlation with the antioxidant activity of the extracts. Among all the tested extracts the highest amounts of total phenolic and total flavonoids content were found in methanol extract of in vivo grown plants. The antioxidant activity of tested samples followed the order in vivo plant extract > callus extract > in vitro extract. The highest reducing power, 2,2-azino-bis-(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging, and chelating power were found in methanol extracts of in vivo grown red clover, while the chloroform fraction of in vivo grown plants showed the highest 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging, superoxide anion radical scavenging and hydrogen peroxide scavenging compared to the other tested extracts. A significant correlation was found between the antioxidant activity of extracts and their total phenolic and total flavonoid content. According to the findings, the extract of in vitro culture of red clover especially the callus tissue possesses a comparable antioxidant activity to the in vivo cultured plants’ extract.

1. Introduction
As a member of the family Leguminosae or Fabaceae, Trifolium pratense L. (red clover) is a short-lived biennial plant which serves as food for livestock, but also as a health food for humans [1].

Red clover (Trifolium pratense L.) has high concentrations of isoflavonoids, compounds largely distributed in the Leguminosae family [2]. Many isoflavone preparations obtained from red clover are currently available as nutritional supplements [3]. Isoflavonoids are secondary metabolites divisible into isoflavones and pterocarpsans. The main isoflavones in red clover are biochanin A and formononetin, both of which are found in abundance in leaves [4]. It also has antioxidant activity that may result from the presence of different flavonoids and other phenolic compounds such as phenolic acids, clovamides, and saponins. Apart from that, it has also been adopted in traditional medicine to treat whooping cough, asthma, eczema, and eye diseases [5].

As shown in recent years, natural antioxidants discovered in plants have attracted some interest due to their widely acclaimed nutritional and therapeutic values. Antioxidant properties stand to be an essential mechanism of beneficial activity of plant-derived compounds and extracts.

Ethnopharmacological surveys have shed light on the fact that the therapeutic use of even 80% of 122 plant-derived drugs may have a link with their recommendations in traditional medicine [6]. Natural antioxidants have a diversity of biochemical activities, some of which include the inhibition of reactive oxygen species (ROS) generation, direct or indirect scavenging of free radicals, and alteration of intracellular redox potential [7]. Antioxidants have functioned to inhibit apoptosis because apoptosis was at first thought to be mediated by oxidative stress [8]. It is known that many
antioxidant substances have anticancer or anticarcinogenic properties [9, 10]. Epigallocatechin-3-gallate (EGCG) in green tea, for instance, has been reported to scavenge free radicals [11] and to hinder carcinogen-induced tumors in the skin, lung, forestomach, and colon of rodents [12].

Therefore, there has been undeniable evidence of interest when it comes to finding natural antioxidants from plant materials.

Studies regarding the bioactivities of various plants have assumed an important position because of the variations in the effectiveness of the plant extract with the solvent for extraction used, plant part used, the plants’ age, and geographic origin. The excessive use of medicinal plants for drug formulation also puts pressure on the need for more biomass of plants which can be met with biotechnological tools like micropropagation.

Our current work aims to evaluate the antioxidant properties of the plant extracts, prepared from the aerial parts of in vivo and in vitro grown red clover. We also seek to examine the effects of extraction solvent on total phenolics, total flavonoids, and antioxidant activities of extracts from both the in vivo and in vitro grown red clover.

2. Materials and Methods

2.1. In Vivo Plant Samples. Seeds of Trifolium pratense L. were purchased from Stock Seed Farms (Murdock, US) and planted in polybags filled with coco peat, sand, and compost in the ratio of 1:1:1. The organic fertilizer was then added to each polybag and kept in the growth room (at temperature of 25 ± 1 °C, 16 hours photoperiod, 40 μmol/m²/s of photon flux density, and 60% relative humidity).

2.2. In Vitro Plant Samples. Some of the purchased seeds were surface sterilized by first placing them under the running tap water for 30 minutes and were rinsed once using sterile distilled water and soaked in 50% Clorox for 2 minutes. The seeds were then washed 5 times using sterile distilled water and soaked in 10% Clorox for one minute. Again, the seeds were rinsed 5 times using sterile distilled water and dipped in 70% ethanol for 1 minute (inside laminar flow chamber). As the final step, the seeds were rinsed 5 times using sterile distilled water and blotted on sterilized filter paper. The MS (Murashige and Skoog) medium, without the addition of any hormones, served to germinate the sterilized seeds. Cultures were stored in growth room (at 25 ± 1 °C, 16 hours photoperiod, 40 μmol/m²/s of photon flux density, and 60% relative humidity) until the grown plants are deemed suitable to be used for further investigation.

The in vitro regenerated red clover after six weeks of culture was used as one of the plant materials in our current study.

The callus tissue of red clover was also produced using MS medium containing 1.5 mg/L BAP (6-benzylaminopurine) and 0.5 mg/L 2,4-D (2,4-dichlorophenoxyacetic acid). The node explants of 6 weeks old in vitro grown plants were cultured in the media. The six-week-old callus was collected as one of the in vitro plant materials/samples.

2.3. Extract Preparation. The aerial parts of in vivo and in vitro grown plants and also the callus obtained from in vitro culture were collected and dried in the dark. The dried samples were powdered in an electronic blender before being used for solvent extraction. For the preparation of extract, 25 g of fine powder was extracted with 100 mL of 95% methanol at room temperature for 48 hours. The extracts were filtrated through Whatman number 1 and combined and this was followed by a concentration using rotary evaporator under pressure that was reduced at 45 °C. The filtrate obtained was suspended in distilled water (25 mL) and n-hexane (50 mL) was added to it, where the mixture was shaken well and the layers were enabled to be separated for 6 h. After separation of n-hexane layer again 50 mL of n-hexane was added to get the n-hexane fraction. In a similar manner, the protocol was repeated with the rest of the solvents (ethyl acetate and chloroform). Each fraction obtained was dried using a rotary evaporator [13]. The dry extract obtained with each solvent was weighed and the percentage yield was expressed in terms of the air-dried weight of plant materials. Samples were stored in an airtight container at –20 °C until it was time to conduct further analysis.

2.4. Determination of Antioxidant Activities

2.4.1. Total Phenolic Content. The total phenolic content of the obtained extracts was spectrometrically analyzed in adherence to the Folin-Ciocalteu method [14]. In short, 100 μL of each extract (dissolved in methanol) or gallic acid standard solution was mixed with 2 mL of 2% (w/v) sodium carbonate solution. The mixture was then incubated for 5 minutes, and afterwards 100 μL of Folin-Ciocalteu reagent was added. After being left for 30 min at room temperature for color development, absorbance was measured at 750 nm using a spectrophotometer. Results are expressed as mg gallic acid equivalents (GAE) per gram dry matter of sample.

2.4.2. Total Flavonoid Content. Total flavonoid content was ascertained based on the method by Zhishen et al. [15]. In brief, 50 mg of each fraction was dissolved in 10 mL of 80% aqueous methanol and filtered through Whatman filter paper number 42 (125 mm). In a 10 mL test tube, 300 μL of each extract, 3.4 mL of 30% methanol, 150 μL of 0.5 M NaNO₂, and 150 μL of 0.3 M AlCl₃6H₂O were added and mixed, followed by 5 min incubation and the addition of 1 mL of NaOH (1 M). Absorbance was measured at 510 nm with a spectrophotometer. The standard curve for total flavonoids was made using rutin standard solution (0–100 mg/L) using the same aforementioned procedure. The total flavonoid content was shown as milligram of rutin equivalents (CTE) per gram dry matter of extract.

2.4.3. Antioxidant Assays. Each sample was dissolved in 95% methanol at a concentration of 1 mg/mL and then diluted in order to prepare the series concentrations for antioxidant assays. Reference chemicals were used for comparative purposes in all assays.
2.4.4. **DPHH Radical Scavenging Activity Assay.** The DPPH radical scavenging assay was conducted following the method of Zhu et al. [16]. In brief, 2 mL of DPPH solution (0.1 mM, in methanol) was blended with 2 mL of the samples at varying concentrations (50, 100, 150, 200, 250, and 300 μg/mL). As the next stage, the reaction mixture was shaken and incubated in the dark at room temperature for 30 min, and the absorbance was read at 517 nm against the blank. Ascorbic acid and rutin standard as positive controls were prepared in a similar manner, as for the test group except for the antioxidant solution’s replacement. The inhibition of the DPPH radical by the sample was calculated based on the formula below:

\[
\text{DPPH scavenging activity (\%)} = \left[ \frac{\text{absorbance of control} - \text{absorbance of sample}}{\text{absorbance of control}} \right] \times 100.
\]

2.4.5. **Superoxide Anion Radical Scavenging Assay.** The assay for superoxide anion radical scavenging activity leaned on a riboflavin-light-NBT system [17]. The reaction mixture had 0.5 mL of phosphate buffer (50 mM, pH 7.6), 0.3 mL riboflavin (50 mM), 0.25 mL phenazine methosulphate (PMS) (20 mM), and 0.1 mL nitro blue tetrazolium (NBT) (0.5 mM), before 1 mL sample solution was added at varying concentrations (50, 100, 150, 200, 250, and 300 μg/mL). Reaction began as the reaction mixture was illuminated with different concentrations of the extracts using a fluorescent lamp. After 20 min of incubation, the absorbance was measured at 560 nm. Ascorbic acid was used as standard. The percentage of inhibition of superoxide anion generation was calculated based on the following formula:

\[
\text{Scavenging activity (\%)} = \left( 1 - \frac{\text{absorbance of sample}}{\text{absorbance of control}} \right) \times 100.
\]

2.4.6. **ABTS Radical Scavenging Assay.** The ABTS radical scavenging assay was performed adhering to the method of Re et al. [18] with slight modification. The ABTS radical was generated through the oxidation of ABTS with potassium persulfate. In brief, the ABTS solution (7 mM) had reacted with potassium persulfate (2.45 mM) solution and was stored in the dark for 12–16 h to produce a dark coloured solution containing ABTS radical cation. Before being used in the assay, the ABTS radical cation was diluted with 50% methanol for an initial absorbance of about 0.70 (+ 0.02) at 745 nm, with the temperature control fixed as 30°C. Free radical scavenging activity was evaluated by mixing 3 mL of ABTS working standard with 300 μL of test sample (50, 100, 150, 200, 300, 400, and 500 μg/mL) in a microcuvette. The decrease in the absorbance was measured at the exact time of 1 min after mixing the solution until it reached 6 min. The final absorbance was noted then. The inhibition percentage was calculated based on the following formula:

\[
\text{Scavenging effect (\%)} = \left[ \frac{\text{absorbance of control} - \text{absorbance of sample}}{\text{absorbance of control}} \right] \times 100.
\]

2.4.7. **Hydrogen Peroxide Scavenging Activity.** The capability of scavenging hydrogen peroxide by the extract was determined based on the method of Ruch et al. [19]. A hydrogen peroxide solution (2 mM) was prepared in 50 mM phosphate buffer (pH 7.4). Aliquots (0.1 mL) of the extracted sample (different concentration of 50, 100, 150, 200, 250, and 300 μg/mL) were transferred into the test tubes and their volumes were made up to 0.4 mL with 50 mM phosphate buffer (pH 7.4). After adding 0.6 mL hydrogen peroxide solution, tubes were vortexed and the absorbance of the hydrogen peroxide at 230 nm was determined after 10 min, against a blank. The abilities to scavenge the hydrogen peroxide were calculated based on the following equation:

\[
\text{Hydrogen peroxide scavenging activity} = \left( 1 - \frac{\text{absorbance of sample}}{\text{absorbance of control}} \right) \times 100.
\]

2.4.8. **Reducing Power Assay.** The reducing powers of the samples were determined following the method of Atmani et al. [20]. Two millilitres of each extract solution (300 μg/mL) was mixed with 2 mL of phosphate buffered saline (0.2 M, pH 6.6) and 2 mL of potassium ferrocyanate (10 mg/mL). The incubation for this mixture was set at 50°C for 20 min. In the next stage, 2 mL of trichloroacetic acid (100 mg/L) was added to the mixture. In a test tube, a volume of 2 mL from each of the above mixtures was mixed with 2 mL of distilled water and 0.4 mL of 0.1% (w/v) ferric chloride. The absorbance was measured at 700 nm after reaction was started for 10 minutes. The increased absorbance of the reaction mixture suggested that the reducing power was high.

2.4.9. **Chelating Power.** The ability of the extract to chelate iron (II) was estimated based on the method of Dinis et al. [21] with minimal modification. Various sample solutions (50–300 μg/mL) were prepared with dissolving the extracts in the methanol. An aliquot of each sample (200 μL) was mixed with 100 μL of FeCl₂·2H₂O (2 mM) and 900 μL of methanol. After 5 min incubation, an initial reaction was fuelled by the addition of 400 μL of ferrozine (5 mM). After 10 min incubation, the absorbance at 562 nm was recorded. The percentage of the chelating activity was calculated based on the following equation:

\[
\text{Chelating activity (\%)} = \left[ \frac{\text{absorbance of control} - \text{absorbance of sample}}{\text{absorbance of control}} \right] \times 100.
\]
Table 1: Total phenolic, total flavonoid, and extraction yield of methanol extract and soluble fractions of in vivo and in vitro grown plants (aerial parts) and also callus tissue of Trifolium pretense.

| Plant extract | Total phenolic (mg gallic acid/g dry sample) | Total flavonoid (mg rutin equivalent/g dry sample) | Extraction yield (%) |
|---------------|---------------------------------------------|--------------------------------------------------|----------------------|
| In vivo       |                                             |                                                  |                      |
| Methanol extract | 46.88 ± 1.07a                              | 26.61 ± 0.92b                                   | 13.89 ± 0.54a        |
| n-Hexane fraction | 30.52 ± 0.72d                              | 16.06 ± 1.58d                                   | 10.79 ± 0.59c        |
| Ethyl acetate fraction | 27.57 ± 0.49g                              | 11.71 ± 1.43g                                   | 6.39 ± 1.12c         |
| Chloroform fraction | 40.17 ± 0.88b                              | 19.56 ± 1.11b                                   | 12.23 ± 0.54b        |
| In vitro      |                                             |                                                  |                      |
| Methanol extract | 31.94 ± 1.68c                              | 13.03 ± 0.79df                                  | 10.84 ± 0.72c        |
| n-Hexane fraction | 20.06 ± 0.41f                              | 8.23 ± 0.96b                                    | 5.20 ± 0.54f         |
| Ethyl acetate fraction | 16.90 ± 1.19b                              | 6.11 ± 0.79b                                    | 2.35 ± 0.5f          |
| Chloroform fraction | 25.43 ± 0.87f                              | 10.39 ± 0.79f                                   | 7.18 ± 0.82f         |
| Callus        |                                             |                                                  |                      |
| Methanol extract | 40.82 ± 1.5b                               | 17.84 ± 0.53c                                   | 11.36 ± 0.55bc       |
| n-Hexane fraction | 31.77 ± 1.14c                              | 12.70 ± 0.94cf                                  | 6.13 ± 0.34ef        |
| Ethyl acetate fraction | 19.23 ± 0.66d                              | 7.21 ± 0.74cd                                   | 2.98 ± 0.66d         |
| Chloroform fraction | 29.25 ± 1.62de                             | 14.02 ± 1.08d                                   | 8.70 ± 0.52d         |

Each value is represented as mean ± SD (n = 3).
Means in the same column not sharing the same letters are significantly different at (Duncan) P < 0.05.

2.5. Statistical Analysis. All assays were carried out in triplicate and their results were expressed as mean ± standard deviation. The EC50 (half-maximal effective concentration) of various fractions for different antioxidant assays were analysed using ANOVA test with least significant difference (LSD) P < 0.05 as a level of significance. Experimental results were examined further for Pearson correlation coefficient of phenolic and flavonoids with different antioxidants assays and its significance was tested using Student's t-test (P < 0.05).

3. Results and Discussion

3.1. Total Phenolic, Total Flavonoid, and Extraction Yield. Good extraction methods prove to be a crucial step for getting extracts with acceptable yields and strong antioxidant activity [22]. The percentage yields of the methanol extract and different fractions of in vivo and in vitro grown plants as well as the callus tissue of red clover are shown in Table 1. The extraction yield of these samples came in a range from 2.35 ± 0.5% to 13.89 ± 0.54%. The results showed that the methanol extraction of in vivo grown plants had illustrated the highest amount of extraction yield, and conversely the extraction yield of in vitro grown plants with ethyl acetate was prominently lower (P < 0.05) when compared to that of the other samples. Being plant secondary metabolites, the phenolics or polyphenols are very important judging from the virtue of their antioxidant activities by chelating redox-active metal ions, inactivating lipid free radical chains, and avoiding the hydroperoxide conversions into reactive oxyradicals. The total phenolic contents of the extracts, expressed as gallic acid equivalents, varied from 46.88 ± 1.07 mg GAE/g for the methanol extract of in vivo grown plants to 16.9 ± 1.19 mg GAE/g for the ethyl acetate extract of in vitro grown plants (Table 1). In all in vivo and in vitro plants and also callus tissue, the methanolic extract had illustrated the highest total content of phenolic, whereas the content obtained with ethyl acetate was much lower (P < 0.05), which is similar to the reports compiled by Sahreen et al. [23] and Ao et al. [24]. A possible justification would be due to the formation of complexes by a part of phenolic compounds with carbohydrates and proteins, which are more extractable in methanol than in other solvents that have been emphasized in this study. Our results do not deviate from those of Parsaeimehr et al. [25] who also found that wild plant, compared to the callus tissue, showed higher extracting phenolic components with regard to some medicinal plants. The rich-flavonoid plants could manifest themselves as good sources of antioxidants that would assist in the enhancement of the overall antioxidant capacity of an organism and protection against lipid peroxidation [26]. The content of total flavonoids is expressed as mg of rutin equivalents per g of dry sample that ranged from 6.11 ± 0.79 to 26.61 ± 0.92, the amounts of which were comparable with results verified in the literatures for other extracts produced [24, 27]. The methanol extract of in vivo grown red clover significantly contained (P < 0.05) higher flavonoids concentration as compared to other samples involved. The lowest flavonoid value in this study was recorded in ethyl acetate fraction of in vitro grown plants (6.11 ± 0.79 mg CTE/g dry sample). The total flavonoid content results were entirely synchronous with those of the total phenolic. It was successfully shown that samples with high level of phenolic content also contain flavonoids in great amount. The rich-flavonoid plants could be a good antioxidant source that would help increase the overall antioxidant capacity of an organism and guard it against lipid peroxidation [26].

3.2. DPPH Radical Scavenging Activity. 2,2-Diphenyl-1-picrylhydrazyl radical is a stable organic free radical with an
absorption band at 517 nm. It loses this absorption when it accepts an electron or a free radical species, resulting in a visually noticeable discoloration from purple to yellow. It can incorporate many samples in a short time span and is vulnerable enough to distinguish active ingredients at low concentrations [28]. Figure 1 highlights the DPPH radical scavenging ability of in vivo, in vitro, and callus samples with different extraction solvents. The differential scavenging activities of the extract against the DPPH system that has been observed could be explained by the presence of different compounds in the fractions. The chloroform fraction of in vivo grown plants showed a reading of the lowest EC$_{50}$ of DPPH radical scavenging ($81.04 \pm 2.33 \mu g/mL$), while the highest EC$_{50}$ belonged to the ethyl acetate fraction of in vitro grown plants (≫300 $\mu g/mL$) (Table 2). Although the DPPH radical scavenging activities of the fractions were less ($P < 0.05$) than those of the ascorbic acid, the study had made a disclosure that in vivo grown plants and callus tissue of red clover have free radical scavengers or inhibitors, possibly acting as primary antioxidants more than in vitro grown red clover. There was an observation on a similar trend in a study of the antioxidant activity of the Artemisia judaica L. extract [29].

3.3. Superoxide Radical Scavenging Activity. As it is a reactive oxygen species, superoxide has some damaging properties that can be imposed to the cells and DNA and subsequently invites various diseases. Thus, a proposal has been established to gauge the comparative interceptive ability of the antioxidant extracts to scavenge the superoxide radical [30]. The superoxide radical scavenging effect of these varying fractions of methanol extract of in vivo, in vitro grown plants as well as the callus tissue of red clover was drawn in comparison with the same doses of ascorbic acid in a range from 50 to 300 $\mu g/mL$ as shown in Figure 2. The results had suggested that the lowest EC$_{50}$ value ($70.69 \pm 1.76 \mu g/mL$) belongs to the chloroform fraction of in vivo samples, whereas the highest value ($260.01 \pm 1.46 \mu g/mL$) belongs to the ethyl acetate fraction of in vitro samples (Table 3). In a dose dependent manner, all of the fractions had scavenging activities

![Figure 1](image_url)
Table 2: DPPH radical scavenging activity of methanol extract and soluble fractions of in vivo and in vitro grown plants and callus tissue of red clover (Trifolium pratense).

| Plant extract          | EC<sub>50</sub> of DPPH radical scavenging activity (µg/mL) | Callus |
|------------------------|----------------------------------------------------------|--------|
| **In vivo**            |                                                          |        |
| Methanol extract       | 94.25 ± 1.15<sup>**</sup>                                |        |
| n-Hexane fraction      | 131.42 ± 3.20<sup>***</sup>                              |        |
| Ethyl acetate fraction | >300<sup>***</sup>                                       |        |
| Chloroform fraction    | 81.04 ± 2.33<sup>**</sup>                                |        |
| Ascorbic acid          | 21.17 ± 0.76<sup>a</sup>                                |        |
| **In vitro**           |                                                          |        |
| Methanol extract       | 205.47 ± 2.90<sup>***</sup>                              |        |
| n-Hexane fraction      | 291.95 ± 2.98<sup>****</sup>                             |        |
| Ethyl acetate fraction | >300<sup>***</sup>                                       |        |
| Chloroform fraction    | 208.86 ± 2.20<sup>****</sup>                             |        |
| Ascorbic acid          | 21.17 ± 0.76<sup>a</sup>                                |        |

Each value in the table is represented as mean ± SD (n = 3).

Means not sharing the same symbols (*, **, and *** ) are significantly different (Duncan) at P < 0.05 in the same row.

Means not sharing the same letters are significantly different (Duncan) at P < 0.05 in the same column.

3.4. ABTS Radical Scavenging Activity. The ABTS radical cation decolourisation test is another widely established approach adopted to evaluate antioxidant activity. Colour reduction shows the decrease of ABTS radical [31]. The samples’ ABTS radical scavenging capability can be ranked on the superoxide radicals. Nonetheless, when compared to the ascorbic acid, the superoxide scavenging activities of the extracts were found to be significantly lower (P < 0.05). This could be due to the presence of flavonoids and other antioxidants in the extract.
ABTS radicals. By contrast, the ethyl acetate fraction of highest radical scavenging activity when it reacted with the other extracts tested (Table 4). Significant differences among in vivo fraction of the EC at the highest concentration, but it was a fact that their radical scavenging abilities on hydrogen peroxide, were remarkably lower (𝑃<0.05) from the EC value that had been obtained for ascorbic acid (Table 5).

### 3.6. Chelating Activity

Ability to chelate or deactivate transition metals, which in turn has the ability to catalyze hydroperoxide decomposition and Fenton-type reactions, is a vital mechanism of antioxidant activity. It was thus considered of importance to screen the iron (II) chelating ability of extracts [27]. All the fractions had ferrous ion chelating ability, but they were remarkably low (𝑃< 0.05) in comparison to catechin. The sequence for the chelating power was in vivo grown samples > callus tissue of samples > in vitro grown samples. The highest chelating power was shown by the methanol extract of in vivo grown plants with the EC value of 49.11 ± 0.97 μg/mL, whilst the lowest was found in ethyl acetate fraction of in vitro grown samples with the EC value of 183.44 ± 2.48 μg/mL (Table 6). The ion chelating data with different measurements of concentrations (50–300 μg/mL) suggested that ferrous ion chelating effects of all the fractions of in vivo and in vitro grown plants as well as callus tissue of red clover would be rather advantageous to offer protection against oxidative damage.

### 3.7. Reducing Power Activity

The reducing power of the extract, which potentially serves as a significant reflection of the antioxidant activity, was ascertained using a modified Fe³⁺ to Fe²⁺ reduction assay, whereby the colour of the test solution, which was yellow, transforms to various hues of green and blue, based on the extent of the reducing power of the samples. The presence of the antioxidants in the samples leads to Fe³⁺/ferricyanide complex reduced to the Fe²⁺ form
and Fe$^{3+}$ can be monitored through the measurement of the formation of Perl's Prussian blue at 700 nm [33].

In the reducing power assay, the presence of reductants (antioxidants) in the fractions would bring about the reduction of Fe$^{3+}$/ferricyanide complex to the ferrous form by giving away an electron. Increasing the absorbance at 700 nm implies an increase in its ability to reduce. The sequence for this reducing power was as follows: in vivo samples $>$ callus tissue $>$ in vitro samples of red clover. Some degrees of electron-donating capacity were found in all examined extracts. Among the examined extracts the methanol extract of in vivo samples showed the highest reducing power with the absorbance of $1.05 \pm 0.07$ at 700 nm, so this extract could act as electron donors and also could convert free radicals to more stable products [34], although, in comparison with the positive control (ascorbic acid), it is significantly lower (Table 7).

### Table 5: Hydrogen peroxide scavenging of methanol extract and soluble fractions of in vivo and in vitro grown plants and callus tissue of red clover (Trifolium pratense).

| Plant extract         | In vivo | $EC_{50}$ of hydrogen peroxide (µg/mL) | In vitro | Callus |
|-----------------------|---------|--------------------------------------|----------|--------|
| Methanol extract      | 103.44 ± 1.47$^{**}$ | 219.86 ± 1.57$^{***}$ | 141.74 ± 1.93$^{***}$ |
| n-Hexane fraction     | 270.56 ± 1.72$^{**}$ | $\geq 300^{***}$          | 287.63 ± 1.59$^{***}$ |
| Ethyl acetate fraction| 138.16 ± 1.93$^{***}$ | $>300^{***}$            | 132.26 ± 2.03$^{b}$  |
| Chloroform fraction   | 88.35 ± 1.27$^{b}$   | 231.49 ± 2.02$^{***}$    | 146.31 ± 1.67$^{d**}$ |
| Ascorbic acid         | 26.84 ± 0.83$^{a}$   | 26.84 ± 0.83$^{a}$       | 26.84 ± 0.83$^{a}$   |

Each value in the table is represented as mean ± SD ($n = 3$).
Means not sharing the same symbols ($*$, $**$, and $***$) are significantly different (Duncan) at $P < 0.05$ in the same row.
Means not sharing the same letters are significantly different (Duncan) at $P < 0.05$ in the same column.

### Table 6: Chelating activity of methanol extract and soluble fractions of in vivo and in vitro grown plants and callus tissue of red clover (Trifolium pratense).

| Plant extract         | In vivo | $EC_{50}$ of chelating power (µg/mL) | In vitro | Callus |
|-----------------------|---------|-------------------------------------|----------|--------|
| Methanol extract      | 49.11 ± 0.97$^{b}$   | 142.87 ± 1.71$^{***}$         | 72.56 ± 1.16$^{d**}$ |
| n-Hexane fraction     | 52.33 ± 1.97$^{**}$  | 131.84 ± 2.05$^{b***}$        | 67.52 ± 2.15$^{c***}$ |
| Ethyl acetate fraction| 105.67 ± 1.56$^{**}$ | 183.44 ± 2.48$^{***}$         | 118.23 ± 2.02$^{**}$ |
| Chloroform fraction   | 86.32 ± 1.89$^{d**}$ | 161.75 ± 1.36$^{e***}$        | 60.17 ± 1.42$^{b}$  |
| Catechin              | 22.76 ± 0.37$^{a}$   | 22.76 ± 0.37$^{a}$            | 22.76 ± 0.37$^{a}$  |

Each value in the table is represented as mean ± SD ($n = 3$).
Means not sharing the same symbols ($*$, $**$, and $***$) are significantly different (Duncan) at $P < 0.05$ in the same row.
Means not sharing the same letters are significantly different (Duncan) at $P < 0.05$ in the same column.

3.8. Correlation with Antioxidant Activities and Phytochemical Contents. Through the correlation analysis for phytochemical contents with $EC_{50}$ values of radical scavenging activity and antioxidant ability of the extract of red clover and its various soluble fractions, the phenolic and flavonoid contents had exhibited excellent association with DPPH, superoxide, ABTS radical scavenging activities, and reducing power of in vivo, in vitro, and callus samples (Tables 8, 9, and 10). Erkan et al. [35] reported a close correlation between radical scavenging activity and total phenolic content of extract from various natural sources. Moreover, for the in vivo samples, $EC_{50}$ of hydrogen peroxide presented an important correlation with phenolics while nonsignificant with flavonoids, whereas for the in vitro samples hydrogen peroxide demonstrated a remarkable correlation with both phenolics and flavonoids. Hydrogen peroxide of callus samples did not shed light on any correlation with phenolics and flavonoids. Chelating power of in vivo samples pointed to a significant correlation with flavonoids but nonsignificant correlation with phenolics while for the callus samples it was found with both phenolics and flavonoids and for the in vitro samples chelating power did not point to any correlation with phenolics and flavonoids. Our results are consistent with those found by Sahreen et al. [23] who reported that there is existence of a strong relationship between phytochemical contents and DPPH and superoxide and ABTS radical scavenging.

### 4. Conclusion

The present work shows the antioxidant effects of in vivo and in vitro grown plants and callus tissues of red clover. The results also suggested a considerable value in terms of the antioxidant activities of methanol extract and chloroform fraction of aerial parts of the in vivo grown red clover. The fraction’s activity is due to the phenolic and flavonoid contents. It is further suggested by our results that the extract of red clover can be adopted as an effective and safe antioxidant source, despite the fact that the antioxidant activities of methanol extract and chloroform fraction of red clover were lower than that ascorbic acid and rutin as positive controls. It is safe to sum up that red clover is consumed...
Means not sharing the same letters are significantly different (Duncan) at $P < 0.05$.

**Table 7:** Reducing power of methanol extract and soluble fraction (300 µg/mL) of in vivo and in vitro grown plants and callus tissue of red clover (*Trifolium pratense*).

| Plant extract          | In vivo                   | Reducing power absorbance at 700 nm |
|------------------------|---------------------------|-------------------------------------|
|                        | Methanol extract          | 1.05 ± 0.07**                       | 0.72 ± 0.03***                     | 0.82 ± 0.03***                     |
|                        | n-Hexane fraction         | 0.88 ± 0.04**                       | 0.52 ± 0.04***                     | 0.65 ± 0.02d**                     |
|                        | Ethyl acetate fraction    | 0.59 ± 0.03d                        | 0.38 ± 0.01d**                     | 0.52 ± 0.03***                     |
|                        | Chloroform fraction       | 0.95 ± 0.03**                       | 0.71 ± 0.04b**                     | 0.91 ± 0.03b**                     |
|                        | Ascorbic acid             | 2.45 ± 0.03                        | 2.45 ± 0.03                        | 2.45 ± 0.03                       |

Each value in the table is represented as mean ± SD ($n = 3$).

Means not sharing the same symbols ($*$, $**$, and $***$) are significantly different (Duncan) at $P < 0.05$ in the same row.

Means not sharing the same letters are significantly different (Duncan) at $P < 0.05$ in the same column.

**Table 8:** Correlation between the antioxidant activity and total phenolic and flavonoid of the extract of in vivo grown *Trifolium pratense*.

| Assays                          | Correlation $R^2$ | Total flavonoid | Total phenolic |
|---------------------------------|-------------------|-----------------|----------------|
| DPPH radical scavenging activity| 0.799**           | 0.745**         |
| Superoxide radical scavenging activity| 0.856**       | 0.903**         |
| ABTS radical scavenging ability| 0.814**           | 0.801**         |
| Hydrogen peroxide radical scavenging activity| 0.414         | 0.598*          |
| Chelating power                 | 0.670*            | 0.500           |
| Reducing power                  | 0.884**           | 0.861**         |

**Correlation is significant at the 0.01 level (2-tailed).**

**Table 9:** Correlation between the antioxidant activity and total phenolic and flavonoid of the extract of in vitro grown *Trifolium pratense*.

| Assays                          | Correlation $R^2$ | Total flavonoid | Total phenolic |
|---------------------------------|-------------------|-----------------|----------------|
| DPPH radical scavenging activity| 0.893**           | 0.876**         |
| Superoxide radical scavenging activity| 0.793**       | 0.806**         |
| ABTS radical scavenging ability| 0.825**           | 0.827**         |
| Hydrogen peroxide radical scavenging activity| 0.784**         | 0.833**         |
| Chelating power                 | 0.502             | 0.441           |
| Reducing power                  | 0.862**           | 0.862**         |

**Correlation is significant at the 0.01 level (2-tailed).**

Our primary finding of this work was that extract of in vitro culture of red clover, especially the callus tissue, possesses an antioxidant activity comparable to the in vivo cultured plants’ extract. It can be concluded that in vitro cultured plants are able to produce and accumulate many medicinally valuable secondary metabolites.

**Conflict of Interests**

The authors declare that there is no conflict of interests regarding the publication of this paper.

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