

## Pre-isolation, isolation and regeneration protoplasts from leaf mesophyll of *in vivo* *Malus domestica* ‘Anna’ cv.

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**Abstract-** To isolate protoplast, a pre-treatment was completed with the order to reduce and identify the phenolic contents round the year to encourage the isolation of protoplasts. Protoplasts from *in vivo* mesophyll leaves of apple cultivar “Anna” was isolated from 15 days old leaves by plasmolyzing in medium containing 90 g L<sup>-1</sup> mannitol for half hour, then 130 g L<sup>-1</sup> mannitol for half hour. Then using enzymatic mixture involving (1.5% cellulase + 0.5% pectinase + 1.5% Macrozyme) Prior to isolation. Anyhow, diverse factors, for example, Osmotic pressure, incubation period, sieve pore size, centrifugation period and hormonal balance was estimated using the techniques for isolation. The quantity of cells was computed as the quantity of cells per square on haemocytometer. A considerable higher yield of protoplast formation was noted in the CPW medium using a pore size of 25 µm with using incubation period for 20 hours. Moreover, the best protoplast regeneration with using of protoplast density of 2.0 x 10<sup>5</sup> in MS medium supplemented by 1.0 mg L<sup>-1</sup>NAA and 0.3 mg L<sup>-1</sup>BAP. We believed that our protocol might encourage the plant recovery using in apple somatic hybridization programs.

**Index terms:** Apple, Hybridization, Cellulase, Pectinase and Macrozyme.

## Pré-isolamento, isolamento e regeneração *in vivo* de protoplastos de mesofilo foliar de *Malus doméstica* ‘Anna’ cv.

**Resumo** -Protoplastos *in vivo* do mesofilo foliar da cultivar de macieira “Anna” foram isolados de folhas com 15 dias de idade através de plasmólise em meios contendo manitol a 90 g L<sup>-1</sup>, por meia hora e em seguida a 130 g L<sup>-1</sup>, pelo mesmo tempo. Anteriormente ao isolamento dos protoplastos foi realizado um pré tratamento com mistura enzimática contendo 1.5 % celulase + 0.5 % pectinase + 1.5 % Macrozyme, a fim de identificar e reduzir compostos fenólicos os quais, durante o ano, estimulam o isolamento de protoplastos. Diversos outros fatores também foram estimados usando as técnicas de isolamento, como por exemplo, pressão osmótica, período de incubação, tamanho do poro da peneira, período de centrifugação e balanço hormonal. A quantidade de células foi calculada por quadrado no hemocitômetro. Um rendimento consideravelmente maior de formação de protoplastos foi observado no meio CPW utilizando um tamanho de poro de 25 µm com período de incubação de 20 horas. Além disso, obteve-se a melhor regeneração de protoplastos com a utilização da densidade de protoplastos de 2.0 x 10<sup>5</sup> em meio MS suplementado por 1,0 mg L<sup>-1</sup>NAA e 0,3 mg L<sup>-1</sup>BAP. Acreditamos que nosso protocolo pode incentivar a recuperação da planta através da utilização de programas de hibridização somática em macieiras.

**Termos para indexação:** Maçã, Hibridização, Celulase, Pectinase e Macrozyme.

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## Introduction

The genus *Malus* has a place with the Rosaceae family and forms with its closely related fruits (*Pyrus* and *Cydonia*) and ornaments (*Amelanchier*, *Aronia*, *Chaenomeles*, *Cotoneaster*, *Crateagus*, *Pyracantha*, *Sorbus*) genera, the subfamily Maloideae (CORNILLE et al., 2012). The apple tree (*Malus domestica* Borkh) is a standout amongst the most financially imperative fruit grown from the berry crops in world agrarian practice. The world production of the way of culture this fruit depends just on 15–20 varieties (GROSS et al., 2014), regardless of the world collection of at least 7000 varieties. The traditional method for apple improvement by choosing the best phenotypes from seedlings become from open-pollinated seeds were supplanted by purposeful hybridization around 200 years prior. However, at first little advancement was made in improvement of apple cultivars through controlled crossing, since their initial domestication, apples have been transported around the world and the cultivated species is now grown in all temperate biomes on Earth (HANCOCK et al., 2008). The accomplishment of the moderately ongoing acquaintances must be credited with the determination of parents with great fruit quality. Illustrious Gala, Fuji, and Jonagold were chosen in the original from the best commercial cultivars, notably Golden Delicious and Delicious, available at the time of crossing.

Breeding of new apple cultivars is challenging. The fundamental technique for conventional apple breeding has experienced the intersection and determination of prevalent individuals from a huge number of seedlings. The lengthy juvenile period of the tree and its vast size, requiring a significant lot of time for assessment and an extensive field space have imposed confinements on apple breeding programs.

In the selection procedure and viable usage of the characteristics of specific varieties under particular developing conditions and ensuring practical productivity. Several generations of backcrossing are typically required before parental material suitable for cultivar growing is available. For quite a long time, response to address them has been easing back because of the nature of fruit tree breeding and reproducing: long term; low effectiveness; and consequently the high expense. For the past 20 years, global systems of fruit geneticists have been working to develop research on fruit hereditary qualities went to improving fruit quality characteristics and also protection from biotic anxieties. Protoplast fusion gives chances to combine the genomes of systematically unique species that can't be consolidated explicitly because of incompatibility hindrances (LIU et al., 2007). The generation of gamete-substantial hybrid and hybrid plants likewise has significant potential as far as quality integration (Davey et al., 2005). This innovation has

gotten a misfortune and restricted consideration. In the meantime, recent studies identified with the generation of physical hybrid breeds have uncovered the potential role of this strategy in enriching plant germplasm, and for the creation of novel cultivars (ANANTHAKRISHNAN et al., 2006; TROJAK-GOLUCH and BERBE' C, 2007; YERMISHIN et al., 2008).

Fast improvements in biotechnological reproducing have abbreviated the timeframe required for fruit tree rearing, and such systems are presently being connected to apples. Translating of the apple genome (VELASCO et al., 2010) has given knowledge into the development of this species.

The application of somatic hybridization may augment the quality pool accessible for apple breeding and improvement, and might be especially imperative for a standout amongst the most vital dwarfing apple rootstocks used around the world, the cultivar 'M9' (*Malus pumila* Mill.; HÖHNLE and WEBER, 2007). 'M9' rootstock introduces a long reproductive cycles, a high level of heterozygosity, and frequent self-incompatibility (ZHANG and LESPINASSE, 2006), which put impediments on the utilization of regular breeding techniques. However, the establishment of a protocol for haploid protoplast isolation and culture is an essential for the efficient somatic hybridization program.

*Malus domestica* 'Anna' cv. which got from the hybrid of Golden Delicious and Red Hadassiya has a decent fruit quality and successfully grown under Egypt conditions. Chilling requirements of such apple cv. is low. Particularly suited to warm winter gardens produces large fresh apples with light green-yellow skin and a slight red blush. Sweet, slightly tart flesh is perfect for crisp eating, cooking and baking. Recommended chilling 200-300 hours, produces at an early age, self-fruitful, anyway a pollinizer, for example, Dorsett Golden will increase production. An apple trees require a period of low temperatures (4 to 10°C) in the fall and winter to allow bud break and growth in the spring. If this period of chilly is inadequate with regards to, the percent of bud that grow will be low and bud break and blossom bud opening will be very sporadic (PUTTI et al., 2003).

Accordingly, the aim of this investigation was to build up a reliable protocol for the isolation and culture of mesophyll protoplasts from the leaves of *Malus domestica* 'Anna' cv. as an initial step to create another cultivar of apple has great quality and low chilling requirements suitable for Egypt natural conditions.

## Materials and methods

This investigation was done at Tissue Culture Unit, NRC, Dokki, Giza, Egypt during the period from 2017 to 2018. All the experimental studies conducted on *In vivo*

*Malus domestica* 'Anna' cv.

### Plant material

All the experimental studies directed on *in vivo* *Malus domestica* 'Anna' cv. which derived from the combination of Golden Delicious and Red Hadassiya. The mother plants grown in Research and Creation Station plantation at El-Nobarria area, Behera Governorate, Egypt. Different experimental studies were took place as follow:

### Pre-protoplast isolation

#### a. Evaluation of phenolic compounds level

To choose the best anti-oxidant treatment viable in overcoming phenolic issue, recorded the levels of phenolic compounds, various periods and concentrate the seasonal fluctuation of phenolic. For this, Five leaves were collected from different three mother plants at various periods (Fig 5A) during all the year, i.e., March, June, September and December (at first seven days of every month) record the levels of phenolic compounds (free, conjugated and total).

**b. Anti-oxidants treatments** -Basic investigation was intended for *In vivo* explants (Fig. 5B) treatment by using three anti-oxidant types (Citric acid, P.V.P and Ascorbic acid) at various concentrations, to determine the best treatment prevailing with regards to reducing or taking out phenolic compound accumulation and thus improved protoplast isolation. Anti-oxidant treatments applied as pretreatments were by dipping the explants in the following solutions for two hours: 1) Control: sterilized distilled water; 2) 0.1% Ascorbic acid (100 mg L<sup>-1</sup>); 3) 0.15% Citric acid (150 mg L<sup>-1</sup>); 4) 0.5% P.V.P. (500 mg L<sup>-1</sup> Polyvinylpyrrolidene); 5) 0.1% Ascorbic acid + 0.15% Citric acid; 6) 0.1% Ascorbic acid + 0.5% P.V.P.; 7) 0.15% Citric acid + 0.5% P.V.P.; 8) 0.1% Ascorbic acid + 0.15% Citric acid + 0.5% P.V.P.

### Protoplast isolation

**Leaf disinfection** -1. Collected the new emerged leaves of *in vivo* from the mother plants (Fig 5A); 2) Transferred directly to the tissue culture laboratory; 3) Subjected to the running water for 15 minutes to get rid of dirt's and germs; 4) Immersing in soap solution for 5 minutes; 5) Then immersing in 10% Clorox solution (0.5 % NaOCl) commercial bleach with two drops of Tween -20 for 10 minutes; 6) And finally immersed in sterilized distilled water 3 times for 5 minutes, each.

**Plasmolysis treatments** - The leaves were dipped in CPW medium (for one hour) with the following additives: 1) Control: 0 mannitol + 0 sucrose ; 2) 90 mg L<sup>-1</sup> mannitol + 0 sucrose ; 3) 130 mg L<sup>-1</sup> mannitol + 0

sucrose; 4) 0 mannitol + 210 mg L<sup>-1</sup> sucrose; 5) 90 mg L<sup>-1</sup> mannitol for half hour then 130 mg L<sup>-1</sup> mannitol for another 30 minute.

**Enzyme mixtures** - Different enzyme mixtures were evaluated to find out the most effective combination on protoplast isolation from *In vivo* mesophyll leaves. The tested enzymes mixtures were as follow: 1) EM1: (1.5% cellulase + 1.0% pectinase + 1.5% Macrozyme); 2) EM2: (1.0% cellulase + 1.0 % pectinase + 1.0% macerozyme); 3) EM3: (1.0% cellulase + 1.5% pectinase + 1.0 % macerozyme); 4) EM4: (1.5 % cellulase + 1.5 % macerozyme); 5) EM5: (2% cellulase + 1.5% macerozyme+ 1.0 % pectinase); 6) EM6: (1.5 % cellulase + 1.0 % pectinase); 7) EM7: (1% cellulase + 1.0 % macerzyme + 0.2% pectinase).

**Digestive enzymes medium** - Each enzyme mixture under study was dissolved in CPW salts (FREARSON, et al., 1973) which contents: KH<sub>2</sub>PO<sub>4</sub>: 27.2 mg L<sup>-1</sup>; KNO<sub>3</sub>: 101 mg L<sup>-1</sup>; CaCl<sub>2</sub>. 2H<sub>2</sub>O: 1.480 mg L<sup>-1</sup>; MgSO<sub>4</sub>. 7H<sub>2</sub>O: 246 mg L<sup>-1</sup>; KI: 0.16 mg L<sup>-1</sup>; CuSO<sub>4</sub>. 5H<sub>2</sub>O: 0.025 mg L<sup>-1</sup>; 13% mannitol and pH: 5.8. In addition, the solution was filter sterilized by passing through 0.2 µm pore size "sartorius" membrane filter.

**Effect of osmotic pressure factor** - Sucrose, mannitol and glucose were the principle osmotic pressure factors applied at a rate 90, 130 and 210 g L<sup>-1</sup> individually whereas every source added to CPW salts medium for identifying the ideal osmotic pressure factor, prevailing with regards to succeed in optimizing the osmotic pressure inside and outside (medium osmotic pressure) protoplast valuable to produce rounded protoplast (suitable protoplasts) without occurrence plasmolysis or burst.

**Effect of incubation period** - *In vivo* leaf strips (Fig 5B) immersed in the suitable enzyme mixture were incubated for various periods i.e., 12, 16, 20 and 24 hours to affirm the best incubated time frame actuated the highest viable protoplast yield.

**Effect of shaking (Shaking speed and Shaking period):** Different shaking speed i.e., 50, 100, 75 and 125 rpm with different periods i.e., 15, 30, 45 and 60 min. were tested to detect the suitable speed and period which encouraged the highest protoplast yield (Fig 5C).

### Purification

**Effect of sieve pore size** - The simple experiment, trial was intended to consider the impact of various sieve pore sizes on the rate of purging levels through disposing of debris and processed cell divider buildups. Sieve with various pore sizes were tried, i.e., 25, 50 and 75

µm to choose the best pore size encouraged the highest purification without any hazard on protoplast yield.

#### Effect of centrifugation (speed and period):

Different centrifugation speeds i.e., 500, 1000 and 1500 rpm speeds were used to confirm the best speed augmented protoplast cleaning and reducing protoplasts damage. Moreover, different periods i.e., 5, 7.5 and 10 minutes were tested to detect the suitable period encouraged the highest protoplast purification with reducing protoplasts damage.

#### Protoplast culture:

**Effect of medium type** - In this experiment the isolated protoplasts of *In vivo Malus domestica* 'Anna' cv. were refined on various media types i.e., MS (Murashige and Skoog, 1962), KM (Kao and Michayluk, 1975) and B5 (Gamborge, 1968) to choose the best culture medium type gave the most elevated protoplast development.

**Impact of protoplast:** Different protoplast densities (0.5, 1, 1.5, 2.0 and 2.5  $10^5$ /ml) were tried to affirm the reasonable protoplast density enhanced the best protoplast development.

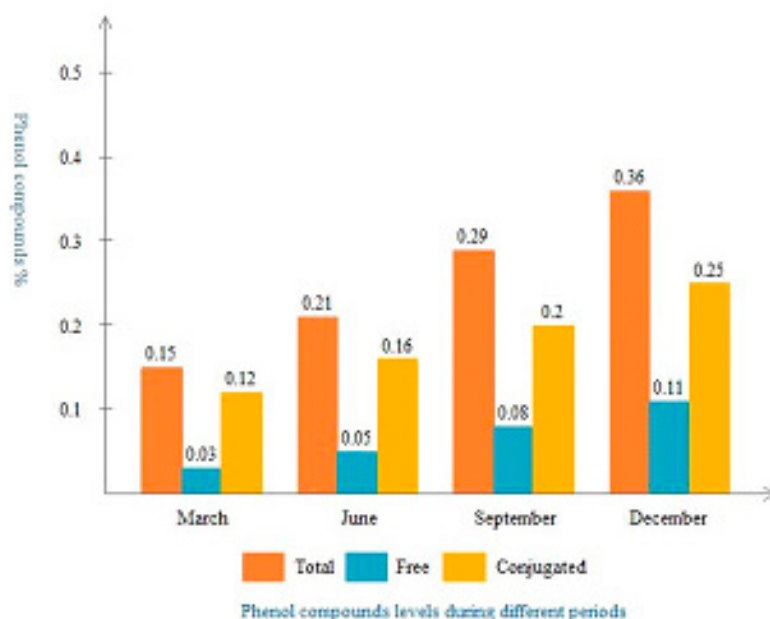
**Effect of hormonal balance** -Hormones were refined on MS medium supplemented with NAA (1, 2 and 3 mg L<sup>-1</sup>) was added to the development culture media at three levels, each level was combined with each one of the following BAP concentrations (0.1, 0.2 and 0.3 mg L<sup>-1</sup>) as follow: Each experimental unit consisted of Petri dishes (15mm×150mm) which containing protoplast yield. Moreover, Petri dishes were organized as a factorial completely randomized design with three replicates.

**Data and calculation** - Counting of protoplasts was according to strategy for (BLACKHALL et al., 2002). Also, number of cells was figured as the quantity of cells per each square on haemocytometer. The final count of protoplasts per 1 ml was conveyed by the following equation conditions. Total number of cells =  $5n \times 10^4$ . Where: n = the average of number of cells per each square on haemocytometer. Also, scores were connected for protoplast development which ascertained as the rate of cell division and microcallii as pursue: 1) No cell division or microcalli formed; 2) Below average of cell division and microcalli formed; 3) Average number of cell division and microcalli formed; 4) Above average of cell division and microcalli formed; 5) Excellent (the highest) cell division and microcalli formed.

**Statistical analysis** - All treatments used in this study were arranged as factorial experiment in a complete randomized design according to SAS and Statistica 9.0 (StatSoft. Inc. 2009). The obtained data were subjected to analysis of variance and statistically analyzed using standard division (SD).

## Results

**Evaluation of phenolic compounds level** - There was a persistent increment altogether, free, and conjugated phenolic compounds determined during March, June, September, and December periods respectively (Fig. 1). Hence, the lowest level of phenolic compound showed up at the March sample, which demonstrated that the best time for taken the explants for protoplast isolation. Additionally, this information reflects the ideal anti-oxidant treatment expected to lessen or take out the phenolic compounds exist during taking the explants.



**Figure 1-** Evaluation of Phenol compound levels (total, free, and conjugated) during different periods in *Malus domestica* 'Anna' cv. leaves.

### Anti-oxidant treatment

The combination of 0.1% ascorbic acid, 0.15% citric acid and 0.5% PVP treatment brought about the noteworthy decrease of phenolic compounds as compared and other treatments (Table 1). Meanwhile,

the combination between antioxidant solution arrangement and P.V.P. took the second rank in reducing the phenolic compounds pursued by P.V.P. treatment. However, the reverse was true when combination treatment of ascorbic acid, citric acid and P.V.P was used.

**Table 1.** Effect of different treatments on Phenolic compounds, protoplast yield and number of plasmolized cells in *in vivo Malus domestica* ‘Anna’ cv.

| Anti-oxidants (%)      | Phenolic compounds (%) |            | Enzyme mixture | Protoplast yield (10 <sup>5</sup> ) | Osmotic pressure (g L <sup>-1</sup> ) | No. of plasmolized cells (10 <sup>4</sup> ) |
|------------------------|------------------------|------------|----------------|-------------------------------------|---------------------------------------|---|
|                        | Free                   | Conjugated |                |                                     |                                       |   |
| Treatments             | Free                   | Conjugated | EM1            | 1.393A                              | Control                               | 0.157E                                      |
| Control                | 0.090A                 | 0.183E     | EM2            | 1.140B                              | 90 M+0 S                              | 0.300D                                      |
| 0.1 AA                 | 0.080AB                | 0.200E     | EM3            | 0.920C                              | 130 M+0 S                             | 0.630B                                      |
| 0.15 CA                | 0.0767B                | 0.200E     | EM4            | 0.877C                              | 0 M+210S                              | 0.500C                                      |
| 0.5 PVP                | 0.0567C                | 0.227D     | EM5            | 0.687D                              | 90 M+130 M                            | 1.30A                                       |
| 0.1AA+0.15 CA          | 0.0533CD               | 0.250C     | EM6            | 0.250E                              |                                       |   |
| 0.1 AA+0.5 PVP         | 0.0433DE               | 0.260C     | EM7            | 0.247E                              |                                       |   |
| 0.15CA+0.5PVP          | 0.040EF                | 0.300B     |                |                                     |                                       |   |
| 0.1AA+0.15 CA +0.5 PVP | 0.030F                 | 0.340A     |                |                                     |                                       |   |

Means within a column followed by the same letter/s are not significantly different at p=0.05

Note: “AA” means Ascorbic Acid, “CA” Citric Acid, “PVP” Polyvinylpyrrolidene, “EM” Enzyme Mixture, “M” Mannitol, and “S” Sucrose.

### Plasmolysis

Results for plasmolysis demonstrated that soaking source explants in plasmolysis treatment containing 90 g L<sup>-1</sup> mannitol for half hour, then 130 g L<sup>-1</sup> mannitol expanded the quantity of plasmolized cells pursued by plasmolysis arrangement (3) containing 130 g L<sup>-1</sup> mannitol +0 sucrose. In any case, the most reduced numbers of plasmolized cells were delivered from plasmolysis (1) (Control: 0 mannitol + 0 sucrose) (Table 1). Concerning the interaction, between protoplasts source and Plasmolysis treatments it is very apparent that *in vitro* explant treated with the plasmolysis 5 (Plasmolysis for 30 min in CPW 9M + 30 min in CPW 13M) boosted the quantity of plasmolized cells, trailed by *in vivo* explant combination with the equivalent plasmolysis. However, the mix of *in vivo* explant with plasmolysis (4) and plasmolysis (1) incited the least qualities.

### Protoplast isolation

#### Effect of protoplast source and enzyme mixture:

The protoplast yield was increased when mix between *in vitro* source and protein blend 244 EM1 (1.5% cellulase + 0.5% pectinase + 1.5% Macrozyme) treatment was used as compared 245 and the other combination treatment in *in vivo* source and a similar enzyme (Table 1). Nonetheless, EM3 (1% cellulase + 1% pectinase 248 + 1% macerozyme) possessed the second rank in improving protoplast yield at the mean time pursued by EM2 (1%

cellulase + 0.5% pectinase + 1% macerozyme) as appeared in (Table 1) EM6 (1% cellulase + 1% pectinase) was the slightest protoplast yield.

### Protoplast culture

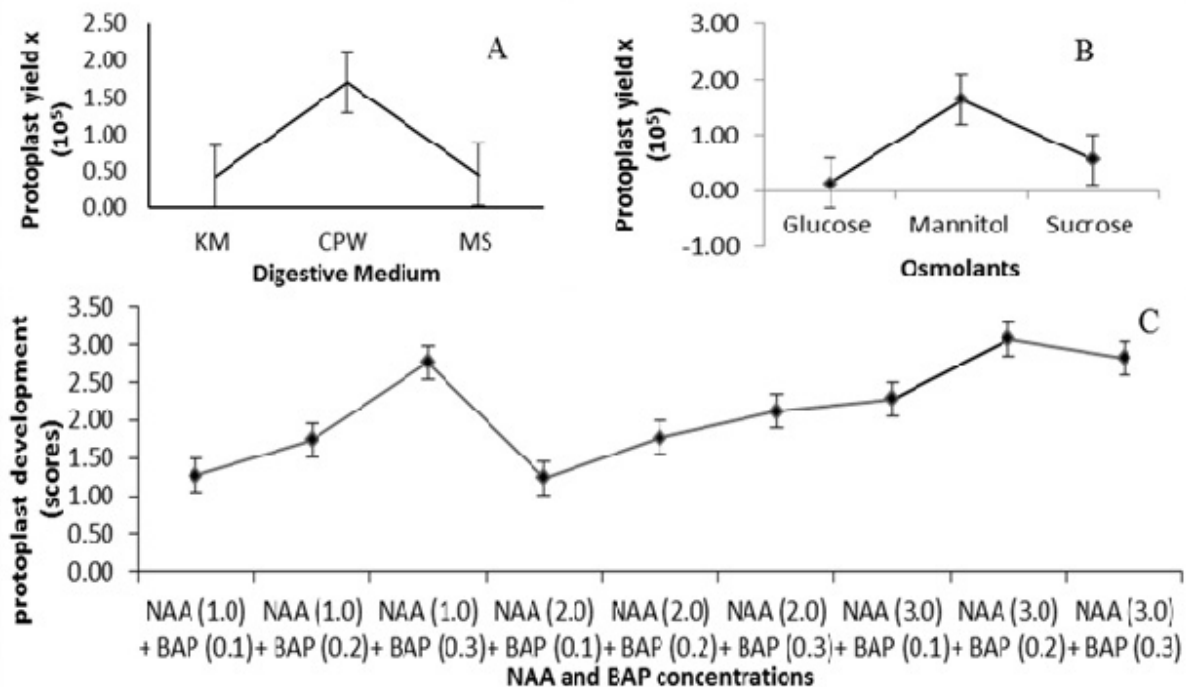
**1. Effect of digestive enzyme medium** - The results presented in (Fig. 2A) revealed for the effect of digestive enzyme medium on protoplast yield (Fig.5 D1). It is noticed that CPW medium was superior in increasing the protoplast yield compared with other media used. However, the lowest result was obtained when using MS culture medium.

**2. Effect of osmotic pressure factor** - The adding of mannitol to the way of culture medium created the highest viable protoplast yield as compared with the other osmotic pressure factors (Fig. 2B). The lowest protoplast yield was acquired when glucose was used as its clear form.

**3. Effect of hormonal balance** - In general, above results summarized that using of 1.0 mg L<sup>-1</sup> NAA and concentrations of BAP under investigation (0.2 and 0.3 mg L<sup>-1</sup>) was the best hormonal equalization used as suitable for maximized protoplast development and expanded cell division (Fig. 2C). The supplementation the culture medium with 3.0 mg L<sup>-1</sup> NAA was favored as the increase of protoplast development. In any case, using free NAA medium gave the most exceedingly high protoplast

development. In addition,  $0.2 \text{ mg L}^{-1}$  of BAP was suggested as it augmented protoplast development compared and the other BAP concentrations under investigation. In any case, the supplementation of  $1.0 \text{ mg L}^{-1}$  NAA and  $0.3 \text{ mg L}^{-1}$  BAP prevailing with regards to enhancing protoplast

development. Value similar concentration of NAA and  $0.2 \text{ mg L}^{-1}$  BAP took the second rank in delivering the best protoplast development. While, the culture medium free from hormones prompted no impact on protoplast development (Fig.5 D1-5).



**Figure 2-** Effect of digestive enzyme medium (A), osmotic pressure (B) and NAA and BAP (C) concentrations on protoplast development of *Malus domestica* 'Anna' cv. leaves.

### Effect of incubation period

It is seen that the using incubation period of 20 hours was viable in improving the protoplast yield treatment with the other incubation periods (Fig. 3). The results of manage the impact of incubation periods on protoplast yield incubation periods for 16 h took the second rank in enhancing the protoplast yield pursued with 24 h incubation period. In any case, the lowest protoplast yield was seen when incubated for 12 h.

**1. Shaking speed** -The best shaking rate that boosted the quantity of protoplast with less damage was 75rpm (Fig. 3). Similarly, expanding shaking speed up to 100rpm decreased protoplasts yield because of expanding damage protoplasts yet the shaking velocity of 50rpm took the second rank in enhancing protoplast yield.

**2. Shaking period** - Information observed in Fig. 3 portrays the impact of shaking period on protoplast yield. It is clear that greatest protoplast yield ( $2.07 \times 10^5$ ) was actuated when the increment-shaking period from 0.0 min. to 30 min. pursued by shaking period for 15 min. and, 45 min respectively. However, the minimal protoplasts yield acquired when shaker was not utilized (control) this might

be because shaking encouraged enzyme mixture digestion of cell walls and free protoplasts appeared.

### 3. Effect of protoplast density

It is clear that increasing cultured protoplast density from  $0.5 \times 10^5$  to  $2.0 \times 10^5$  resulted in enhancing in protoplast development as (3.33) was obtained when cultured density was  $2 \times 10^5$ . Meanwhile, continuous increase of protoplast density up to  $2.5 \times 10^5$  inducted an adverse effect on protoplast development. The above results reflect the importance of using protoplast density  $2.0 \times 10^5$  in maximizing protoplast development (Fig. 3).

### Effect of different treatments on yield and quality of protoplast

**1. Effect of sieve pore size** -The increased sieve pore size results in a decreasing numbers of viable protoplast (Fig. 4A). In the interim, the most elevated of the number of viable protoplast was incited by using a pore size of  $25 \mu\text{m}$  pursued by  $50 \mu\text{m}$  lastly the least protoplasts instigated when  $75 \mu\text{m}$  pore size was used. The previously mentioned outcomes suggested using sieve pore size  $25 \mu\text{m}$  incited the most astounding protoplast number. These outcomes might be because of expanding the sieve

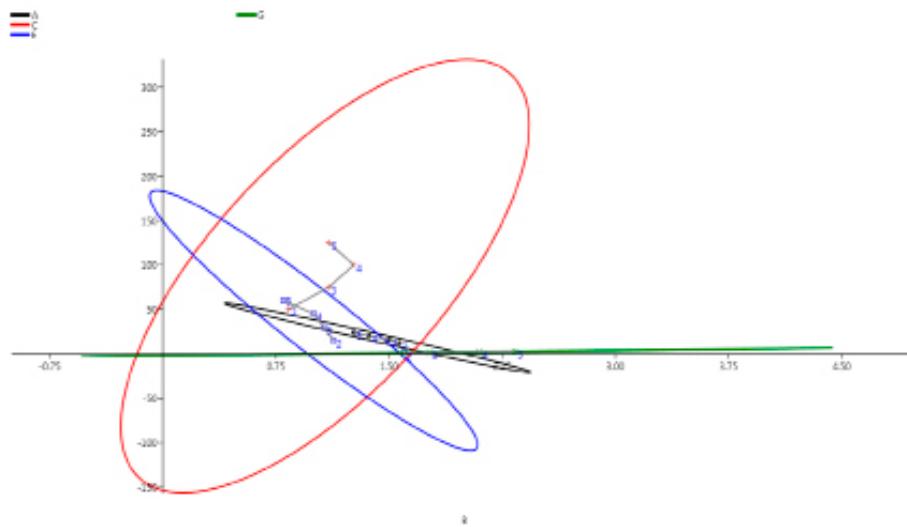
pore size generated higher quantities of protoplasts cell residues, clumps of undigested tissues and debris to pass through the filter and in turn affect badly on protoplast yield.

**2. Effect of centrifugation speed** -The use of centrifugation speed at 1000 rpm was more effective in increasing the number of protoplast followed by 500rpm (Fig. 4B) reflecting on a number of viable protoplast. However, continuous increase in centrifugation speed up to 1500rpm induced the lowest protoplast yield.

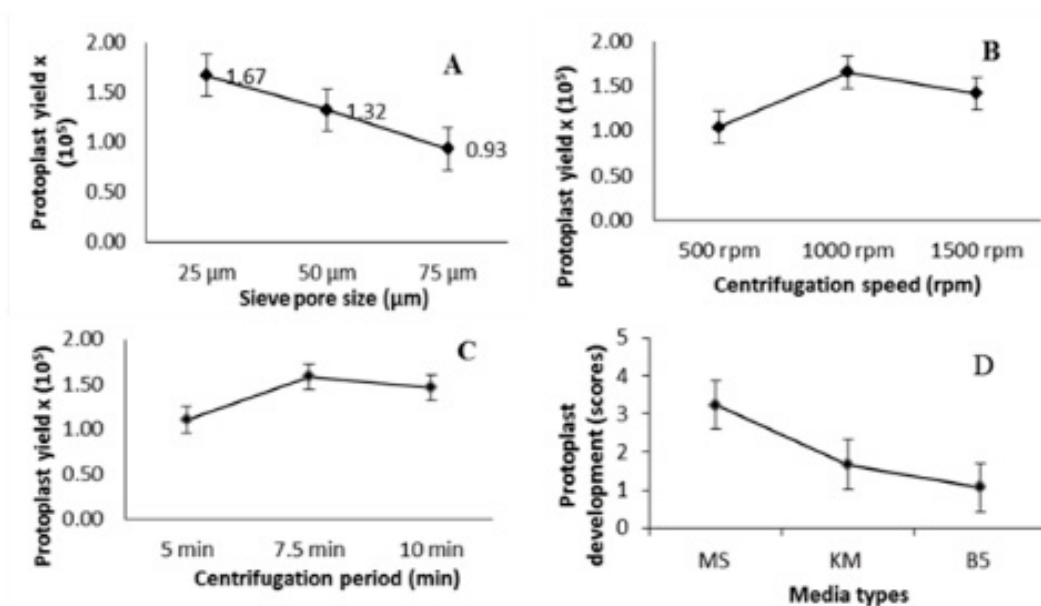
**3. Centrifugation period** -Expanding the centrifugation period up to 7.5 minutes (Fig. 4C) incited appositive impact on the expanding number of

viable protoplast in correlation with other periods under investigation. In the meantime, expanding centrifugation period from 7.5 to 10 minutes brought about reducing protoplast viability. In any case, using centrifugation period 5.0 minutes took the second rank in enhancing protoplast viability.

**4. Effect of medium type** - The effect of different media types on protoplast development can be seen in Fig. 4D. It appears that the superiority of MS medium over both KM and B5 media. However, B5 medium showed the worst effect on protoplast development. The above results indicate the suitability of MS medium for the best protoplast development.



**Figure 3-** Trajectories of points and compressions of protoplast density, shows point projections and corresponding to them yield ellipses at the start and after 3 subsequent points. Points being in the A and B axis in each circle are highlighted and denoted by stars, numbers and squares.



**Figure 4** - Effect of different treatments on yield and quality of protoplast: A) sieve pore size, B) centrifugation, C) Centrifugation period and D) Media types.

## Discussions

The present protocol was the initial step to check the potential of mesophyll leaf tissue using new techniques for *in vivo* isolation in apple protoplast cultures. Strategies like pre isolation and using of antioxidants use in *in vivo* to enhance protoplast generation were rarely used for apple. Numerous endeavors have been made for significant harvests protoplast isolation, including sugarcane, maize, potato, citrus, carrot, cotton, and rice and so on. (RAI et al., 2011) Exposure of protoplasts was likewise published for different species, for example, grape vine, orange tree, lemon, tomato, and tobacco (S`VA`BOVA` AND LEBEDA 2005). Physiologically uniform stages, Protoplasts is an elective that utilizes quite a bit of the extensive cell populace compared to various types of explants, thus, leading towards an opportunity to present new protocols both in *in vivo* and in *in vitro* conditions for efficient isolation regeneration and selection using less space.

However, a limited number of species capable of rebuilding cell walls and under-going mitotic cell divisions to produce callus and normal plant formation. Often, only genotypes carefully selected in many species undergo production of protoplast-derived plants (DAVEY et al., 2005).

In this exploration, we could control essentially polyphenols that restrain mitotic cell division in protoplast isolation following the treatments with varying level of antioxidants, which was correlated with the density of protoplasts. The increase in protoplast efficiency observed for both types of particular treatment application. However, a stronger response of cells was observed when the protoplast from the antioxidant treated cell was extracted. This may be explained by the cells able to reconstruct cell walls infect negligible or reduce phenolic compounds in comparison to the non-treated cells. Similar observations have been accounted for in the protoplast of *In vitro* culture of unfertilized ovules in carrot (KIELKOWSKA AND ADAMUS 2010).

Analysis of the effect of different factors, including time of explant taking, using of anti-oxidant solution on protoplast isolation and culture all the factors have significantly positive role, such as plasmolysis treatments, enzyme mixtures, different media and other than these factors such as shaking, centrifugation and hormonal balance were the most important.

Taking explant in the March sample demonstrated the most reduced phenolic compounds use of anti-oxidant solution 0.1% ascorbic acid + 0.15% citric acid+ 0.5% P.V.P, these outcomes are in accordance with the discoveries of (SAVITA et. al., 2011). They declared that citrus acid and ascorbic acid controlled browning of coconut explant, yet polyvinyl-pyrrolidone was insufficient at the rate of 1 mg L<sup>-1</sup> in controlling oxidation of the phenolic compounds. In addition, introduction to 90 g L<sup>-1</sup>ml mannitol for half hour give preferred results

over 130 g L<sup>-1</sup> ml mannitol which is in concurrence with the discoveries of (SHRESTHA et al., 2007) reported that explant regeneration from cell suspension-derived protoplasts of *Phalaenopsis* plasmolyzed for 30 min in CPW medium with 0.5 M mannitol pursued by 30 min in CPW medium with M mannitol (CPW 13 medium) plasmolyzed protoplast increment respect  $4.5 \times 10^6$  g/ FW protoplasts with 60% viability. (HISAMOTO AND KOBAYASHI, 2010) likewise washed in the mesophyll tissues in a solution of 6% mannitol and was plasmolyzed in CPW medium with 0.5 M mannitol pursued by 30 min in CPW medium 0.7 M mannitol. Using 1.5% cellulase + 1.5% Macerozyme + 0.5% pectinase with CPW digestive related medium delivered high density protoplast, these outcomes adapted to the discoveries of (LIN et al., 2014). They discovered that CPW 13M was the best protein medium used for protoplast detachment from leaves of stone fruit (*Prunus spp.*). Medium supplemented with 1% PVP and 0.5 mM MES helped in the prevention of browning and protoplast cell wall regeneration. (MEHRI 2003) who discovered that CPW 13M was a profoundly proficient medium for digestion related enzymes mixture to isolate protoplast from *prunus carasus L. cv*” Montmorency”.

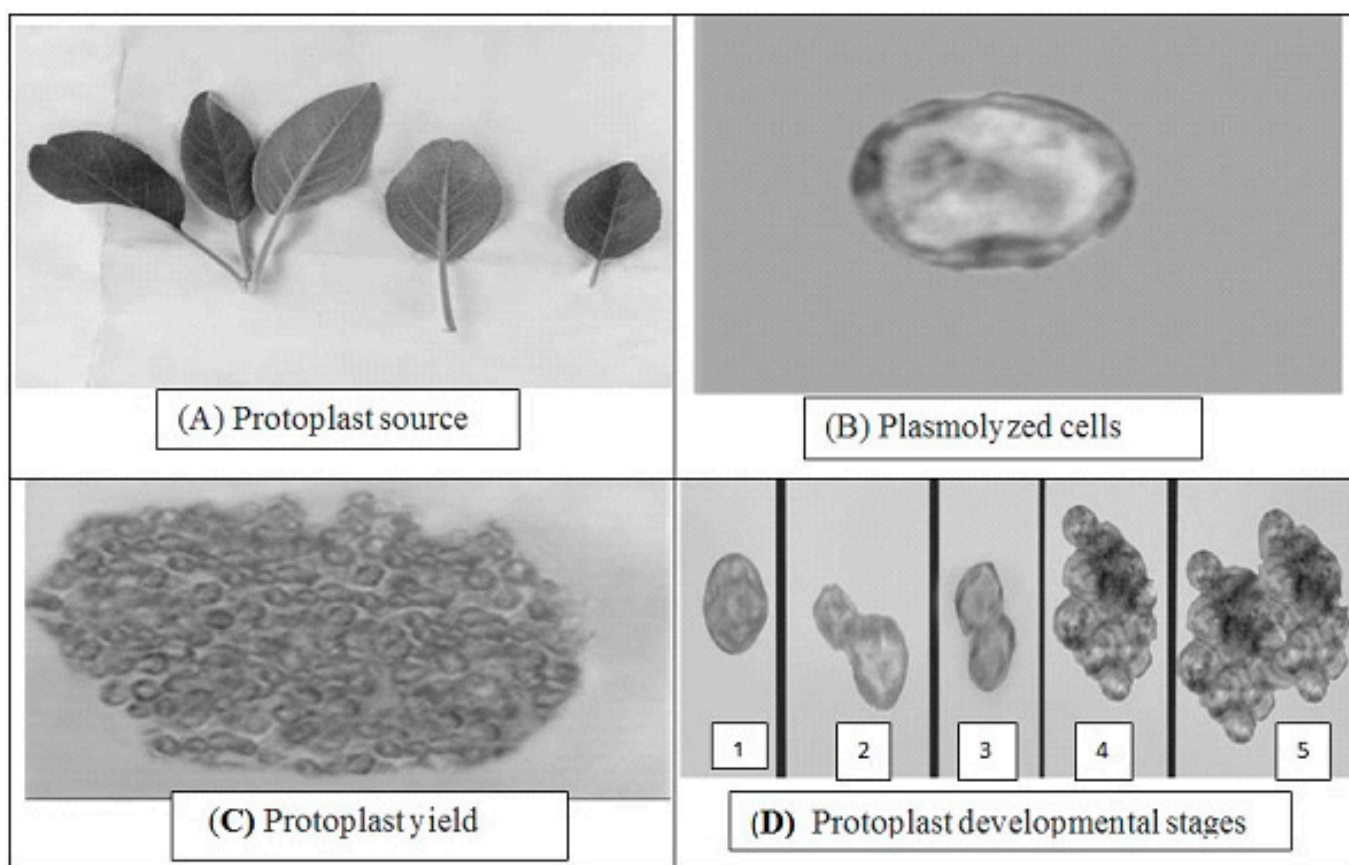
Besides, (JIHONGLIU et al., 2003) cleared up that protoplast isolation from most woody plants are essentially required cellulase onozuka R-10, pectinase, Driselase, Macerozyme and Hemicellulase yet protoplast isolation of most plants as an essentially needs 1-2% cellulase and 0.1-1% pectolyase. Additionally, (PING et al., 2005) they discovered that the best digestion related chemical solution for protoplast isolation of *Vitis davidii* when added 2% cellulase, 0.5% pectinase and 1% macerating protein. Meanwhile, adding mannitol as osmotic pressure factor to the media empowered generation of the highest protoplast numbers as revealed that adding 0.7% mannitol to the incubation medium expanded protoplast viability got from cell suspension of apple cultivars (*Malus domestica* cultivars fuji and Jonagold) and *Malus prunifolia* var ringo. In addition, (MEHRI 2003) got the best yield and viability of protoplast of *Prunus cerasus L.* isolated from leaf mesophyll and leaf callus using enzyme solution containing 13% mannitol and 5mM MES. However, (SEGUI et al., 2006) discovered that the best viability of protoplast from apple (*Malus domestica* var. fuji ) when used 0.8% M mannitol as osmoticum . Besides, Incubation of the explants for 20 hours additionally encouraged in isolation of protoplast, incubated in an enzyme solution at 25°C in the dark for 18 hours’ apple (*Malus domestica* Borkh) explant. Likewise, with (SHRESTHA et al., 2007) who obtained a high amount of protoplast from *Phalaenopsis* when incubated in an enzyme solution in the dark under 28°C for 18 hours. Shaking with incubating of explants in an enzyme solution at 75rpm for 30 min delivered a good yield of protoplasts.



Using a sieve at pore size 25  $\mu\text{m}$  give the best filtrate that the isolation of protoplast of citrus was best with filtration through 50  $\mu\text{m}$  and 30  $\mu\text{m}$  nylon screens. Centrifugation protoplast with speed rate 1000rpm for 7.5min creates a clear layer pattern (QINGHUA ZHANG et al., 2006). They isolated protoplasts of *Citrus unshiu* in the filtrate was additionally cleansed by centrifugation in a 25% sucrose/13% mannitol gradient for 6 min at 88 g. Murashig and Skoog medium was prevalent for the best protoplast with density rate  $2.5 \times 10^5$  in the way of culture medium, best cell division with high protoplast thickness  $0.5\text{-}2.5 \times 10^5$  protoplasts for each ml of pear *Pyrus spp* when refined on MS Medium. (YOO et. al., 2007) also get best results get best results of cell division from protoplasts of apple (*Malus X domestica*) cv. “fuji” when refined on MS medium enriched with 2 mg 2,4-D and 1mg benzyladenine (BA/liter) and 0.8% agar. Other than MS medium, addition to the mix of  $1.00 \text{ mg L}^{-1}$  NAA

and  $0.3 \text{ mg L}^{-1}$  BAP were most appropriate for protoplast recovery. (XIANG et. al., 2004) Who effectively refined the protoplasts of wheat on NN medium enriched with  $2 \text{ mg L}^{-1}$  NAA and  $0.2 \text{ mg L}^{-1}$  BAP at  $28^\circ\text{C}$  in the dark and same were reported with high recurrence of cell division of *Vitis thunbergii* protoplast, when culture medium was enhanced with  $2 \text{ mg L}^{-1}$  NAA and  $0.2 \text{ mg L}^{-1}$  benzyl adenine.

Regarding, planting efficacy and ability protoplast to regenerate plants from pre-medicated explants showed a smooth response, likely to be correlated with different levels of antioxidants. The maximum recovery efficiency that allowed us to regenerate plant cells was higher and fall in a range of 20 to 85 % premeditated depending on the treatments and to that of time and season of application. Similar results were recorded by (RAI et al., 2011). Successful regeneration and selection with different treatments was also reported on protoplast



**Figure 5** - Reflect the protoplast technique on haemocytometer under microscope in *Malus domestica* ‘Anna’ cv. which include (A) protoplast source, (B) Plasmolyzed cells, (C) Protoplast yield (Total number of cells =  $5n \times 10^4$ . Where:  $n$  = the average of number of cells per each square on haemocytometer), (D) protoplast developmental stages (5) protoplast development (1=protoplasts, 2=buding stage, 3= protoplast division, 4=microcalli formation, 5=more microcalli formation).

isolation process of chrysanthemum (KUMAR et al., 2008), carnation (THAKUR et al., 2002) and that citrus (SAVITA et al., 2011).

However, exposure to toxins like polyphenols can result in a decrease and recovery capacity and can create undesired freaks. Despite what might be expected, using procured and techniques may yield higher recovery rate and additionally healthier plants (SHARMA et al., 2010). Subsequently, in this experiment, we applied a pre-medication system with seasonal variation in phenolic level and anti-oxidation to in a mixture of various media enriched with various hormonal levels inserted higher density of protoplasts. These conditions used in this process ensured sufficient favorable conditions to each cell present in the culture. These conditions were additionally used with protoplast isolation of sugar cane (MAHLANZA et al., 2013). Loss of viability is regular in protoplast cultures of several species. (BABAOG˘LU, 2000), (ADITYA AND BAKER 2003), (SRISAWAT AND KANCHANAPOOM 2005), (KIM et al., 2006), and (CHABANE et al., 2007) reported challenges in protoplast cultures. (DAVEY et al., 2005) attributed the decline in viability to be due to the sensitivity of the plasma membrane, due to an inadequate reduction in the osmolarity of the culture medium.

Along these lines, the achieved above protocol can give a premise to the isolation and development of protoplast and to plant recovery framework, beginning from leaves, for the improvement and breeding program of apple cultivars.

## Conclusion

The protocol developed and embraced in this manuscript is proficient for protoplast isolation and recovery of cultivar studied. The results of this exploration likewise recommended that this protocol could be utilized for fusion experiments for somatic hybridization using other cultivars to produce new cultivar suitable for Egypt environmental conditions.

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## Erratum of article:

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### In the page 1, Corresponding author:

#### where it reads:

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### In the page 4,

#### where it reads:

**Impact of protoplast:** Different protoplast densities (0.5, 1, 1.5, 2.0 and 2.5  $10^5$  /ml) were tried to affirm the reasonable protoplast density enhanced the best protoplast development.

#### should read:

**Impact of protoplast density:** Different protoplast densities (0.5, 1, 1.5, 2.0 and 2.5  $10^5$  /ml) were tried to affirm the reasonable protoplast density enhanced the best protoplast development.

### In the page 5,

#### where it reads:

**Effect of protoplast source and enzyme mixture:** The protoplast yield was increased when mix between *in vitro* source and protein blend 244 EM1 (1.5% cellulase + 0.5% pectinase + 1.5% Macrozyme) treatment was used as compared 245 and the other combination treatment *in vivo* source and a similar enzyme (Table 1). Nonetheless, EM3 (1% cellulase + 1% pectinase 248 + 1% macerozyme) possessed the second rank in improving protoplast yield at the mean time pursued by EM2 (1% cellulase + 0.5% pectinase + 1% macerozyme) as appeared in (Table 1) EM6 (1% cellulase + 1% pectinase) was the slightest protoplast yield.

#### should read:

#### **Effect of enzyme mixture:**

The protoplast yield was increased when mix between *In vivo* source and enzyme mixture EM1 (1.5% cellulase + 0.5% pectinase + 1.5% Macrozyme) treatment was used as compared to the other combinations treatments (Table 1). Nonetheless, EM3 (1% cellulase + 1% pectinase 248 + 1% macerozyme) possessed the second rank in improving protoplast yield at the mean time pursued by EM2 (1% cellulase + 0.5% pectinase + 1% macerozyme) as appeared in (Table 1) EM6 (1% cellulase + 1% pectinase) was the slightest protoplast yield.