Research Article

Production Potential of Pot Marigold (*Calendula officinalis*) as a Dual-Purpose Crop

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Abstract | Calendula is mainly grown as a single purpose plant for its flowers or recently for its seeds, whereas information for calendula cultivation for both flowers or petals and seed production is very scarce. A field study was conducted on two seasons to evaluate the effect of petal harvesting on flower heads fresh and dry weights, monthly and cumulative number of flower heads/plant, seed yield, fixed oil percentage and fatty acid analysis of pot marigold (*Calendula officinalis*). A Randomized Complete Block Design (RCBD) was used to arrange the treatments in three replicates, (H): petal harvesting and (C): without petal harvesting (control). Petal harvested plants produced a significantly much more harvestable total flower yield of 297-350 per plant than control with 48-51 flower/plant. Further, petal harvesting has significant effect on the flowers number and it increased 6-7 folds; hence possibly improve the compensation ability of plants to set new buds. Petal harvesting had positive significant effects on plant fresh and dry weights, seed yield but adversely affected flower fresh and dry weights as well as seed oil percent (%). Seed oil percent ranged from 11.76 to 11.94 in petal harvesting treatment compared to control that ranged between 14.01 to 14.38. Petal harvesting resulted in a significant reduction in oil percent by 19 % and 20% when compared to no petal harvesting in the first and second season, respectively. The major constituents of the extracted oil from calendula seeds were calendic acid (45.95-46.27%) and linoleic acid (26.56-26.81%) whereas palmitic acid (5.23-5.32 %) oleic acid (5.87-6.72 %), stearic acid (3.34-3.41%), avenoleic acid (2.15-2.46%) and sterculic acid (3.27-3.89%) were the predominant constituents. It can be said from our results that it is possible to perform eighteen petal harvests to be used for pharmaceutical or coloring and dying purposes and at the same time keep the flowers on the plant and get the highest seed yield for industrial applications.

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Introduction

Calendula (*Calendula officinalis* L.) also known as pot marigold is an annual flowering herb belongs to the Asteraceae family and native to the Mediterranean region and is widely used both ornamentally and medicinally. Calendula is a multi-purposes plant used, for example, in ornamental and culinary uses, in the cosmetic, personal and skin care products, perfume, and food industries throughout the world (Lohani *et al*., 2019; Szopa *et al*., 2020). Calendula is mainly grown as a single purpose plant for its flowers which are rich in bioactive compounds or recently for its seeds. Flower or seed production of calendula is well documented, whereas information for calendula cultivation for both flowers or petals and seed production is very scarce. To the best of our knowledge, the only study that investigated the effect of flower harvesting on the seed yield in calendula is a field study conducted by Wilen *et al*. (2004). They documented the possibility of performing at least three flower harvests to obtain maximum seed yield with an average of 600-700 kg/ha. Up to seven harvests are attainable when flowers are harvested by hand, producing 1.7 tons of dried flower heads yield/ hectare.

Calendula flowers are present for a long period since it continues to bloom for many months in nature over a period of four months (Szopa *et al*., 2020). To obtain raw material derived from flowers, calendula should be harvested immediately after flower opening to avoid losses that would affect the quality of the raw material. Çalışkan and Kurt (2017) had twenty-four harvests from flower heads during 105 days of flowering giving the maximum flowers number of 465.62/plant and essential oil yield of 9.30l/da throughout his experiment. For seed production, leaving the flowers on plants until the seeds mature will result in a considerable loss of the quality characteristics of these flowers such as color, appearance and biochemical components. Moreover, with time, productivity declined due to initiation of the flower senescence. At the 12 days after anthesis, ligulate flowers begin to drop and the flower aging of the was evident, thus starting the process of seed formation (Honório *et al*., 2016).

The capitula (flower head or inflorescence) contains the highest concentration of active substances that are used for medicinal purposes (Stewart and Lovett-Doust, 2003). The bioactive compounds of *C. officinalis* have been investigated, and it comprises essential oils, phenolic acids, carotenoids, steroids, coumarins. Calendula also contains quinines, isoquercitin, rutin, carbohydrate, glycosides, amino acid, saponins and vitamin C (Muley *et al*., 2009; Re *et al*., 2009; Bekdeser, 2019).

As a medicinal plant, calendula flowers and leaves have been used for healing wounds (Honório *et al*., 2016), healing liver, gallbladder and stomach diseases, reducing gastritis and trophic ulcer (Mehta *et al*., 2012). In addition, calendula flowers and leaves are well recognized to exhibit antiseptic, analgesic, anti-emetic, anti-tumor, anti-mutagenic, antioxidant, immune-stimulatory, cytotoxic properties and cardioprotective effect against ischemic heart disease (Jan *et al*., 2017; Verma *et al*., 2018). Moreover, hypoglycemic, gastric emptying and gastroprotective properties, antibacterial, antifungal, spasmolytic, anti-carcinogenic and anti- eczema effects were reported (Khalid and Da Silva, 2012; Bashir *et al*., 2006; Deniz *et al*., 2010; Savić and Gajić, 2021).

Calendula petals are very important as a source of medicinal preparations. The petals have been found to have anti-inflammatory, antimicrobial activities and promote wound healing and may aid in the treatment of dermatologic disorders (Blumenthal *et al*., 2000; Efstratiou *et al*., 2012). Calendula petals has progressively gained its importance as a natural colorant acceptable to food manufacturers since it has two types of pigments that can be employed as yellow and orange natural dyes in the food industry (Ul-Islam and Kumar, 2014).

Presently, calendula can be also grown for seed production where the industrial interest in calendula has developed after discovering that seed has oil content can range from 5-20% (w/w) and comprise of conjugated C18 fatty acid named calendic acid accounts for 50–60% (Wilen *et al*., 2004). Thus, contributing to the rising interest in its use as an emerging industrial non-food oil in paints, coating and varnish industries (Biermann *et al*., 2010). Calendic acid is synthesized in calendula seeds via desaturation of linoleic acid. The chemical and physiological properties of calendic acid and the quick oxidation make it an attractive candidate as a drying oil, raw material or binder in paints, varnishes and plastics offering alternatives to volatile organic compounds (Dulf *et al*., 2013).

One of the major problems with the commercialization of calendula will be the harvesting of the flowers without affecting seed yield (Martin and Deo, 2000). Therefore, this study aimed to study the possibility of growing calendula for its petals and seeds jointly: Seed for industrial applications and petals for medicinal applications. Additionally, study the effect of petal harvesting on seed yield and its content and composition of the fixed oil.

Materials and Methods

The present study was conducted in 2017/2018 and 2018/2019 seasons at the Experimental Farm of Faculty of Agriculture, Cairo University, Egypt. Calendula seeds used for this study were kindly obtained from SEKEM Group of Companies, Cairo-Belbes Desert Road, El Salam City, Cairo, Egypt.

The soil type is classified as a sandy clay loam and the physical and chemical analyses of the experimental soil are presented in Table 1. Average temperature, relative humidity and sunshine hours in the study area in Giza, Egypt, during seasons of 2017/2018 and 2018/2019 are shown in Table 2.

Seeds of calendula were planted in late August. Before transplanting; an application of calcium superphosphate at the rate of 500 kg ha^{-1} as well as the half dose of potassium (in the form of 250 kg ha^{-1} potassium sulfate) was incorporated into the soil. Ammonium nitrate at the rate of 375 kg ha^{-1} was also applied in three separate applications; the first portion was applied a month after transplanting, the second was a month and a half from the first one and the third was a month after the second one (according to the recommendation of the Egyptian Ministry of Agriculture). Individual plot sizes were 6m × 4m. Each plot consisted of four rows spaced at 60 cm. In Mid-October, plants were transplanted into the field on 50 cm between plants. Plants were watered as needed. A randomized complete block design was used to arrange the treatments in three replicates, (H): Petal harvesting and (C): Control (without petal harvesting).

Above ground plant biomass and flower head weights were recorded fresh before drying in a 60°C oven until achieving a stable dry weight. When the flower heads fully opened, they hand-harvested during the experiment. Inner and outer capitulum diameter, fresh and dry weights of plant, flower heads fresh and dry weights as well as seed yield and the cumulative number of flower heads per plant, fixed oil percentage and fatty acid analysis were determined with and without petal harvesting.

Table 1: *Physical and chemical analysis of the soil.*

Clay (%)	Silt (%)	Sand (%)	OM (%)	CaCO3 (%)	EC (dSm^{-1})	pH
35.5	28.8	36.7	1.5	2.7	1.7	7.8

Available nutrients (ppm)				Soluble cations mmolc L^{-1}			Soluble anions mmolc L^{-1}		
N (ppm)	P (ppm)	K (ppm)	Fe	Ca	Mg	Na	HCO_3	Cl	SO_4
45	10	100	14	6.5	2.3	6.2	4.0	4.6	7.0

Table 2: *Average temperature, relative humidity and sun shine hours in the study area in Giza, Egypt, during seasons of 2017/2018 and 2018/2019. Data obtained from the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Egypt.*

	2017/2018			2018/2019		
Months	Temperature average (°C)	Relative humidity average (%)	Sunshine hours	Temperature average (°C)	Relative humidity average (%)	Sunshine hours
October	22.58	54.61	11.40	23.63	55.03	11.41
November	17.17	65.33	10.63	19.01	59.22	10.63
December	14.35	69.52	10.24	13.72	66.25	10.24
January	11.88	70.82	10.46	11.29	51.86	10.46
February	15.34	58.48	11.13	13.16	54.78	11.13
March	19.06	47.30	12.01	15.42	55.18	12.01
April	21.58	45.68	12.93	19.62	46.75	12.93
May	26.64	42.00	13.69	26.93	32.13	13.68

To determine petal yield during the growing season, petals of fully opened flowers were hand-picked from plants during the morning at weekly intervals beginning from early January, until mid-May. In the case of petal removing, we determine fresh and dry weights of petals/plant, the number of flower heads/plant, dry matter percent of petals. Dry weight of petals was recorded after fresh petals were oven dried at 40°C to a constant weight.

Oil extraction and fatty acid analysis

A sample of approximately 10 g of ground seeds was used to determine oil content using Soxhlet extraction apparatus with petroleum ether for eight hours of each replicate. The extracted oil was stored in cleaned plastic bottles under cold dark condition till analysis (Siddiq and Shah, 2016).

Fatty acids and unsaponifiable matter separation

The saponification of an aliquot of the petroleum ether extract was done under reflux with 20 ml of M KOH (10%) at 80°C for 3 hr. Acidification of the reaction mixture was done using HCl (10%) after the extraction of the liberated fatty acids with ether (30 ml), and using distilled water for washing multiple times till acid-free, then drying over anhydrous sodium sulfate. The fatty acids were weighed after evaporation of the solvent in vacuo (Farag *et al*., 1986).

Fatty acid methyl esters preparation

The liberated fatty acids (10 mg) were refluxed with 10 ml (2%) of H_2SO_4 in anhydrous methanol on a water bath at 90°C for 5 hours (Kinsella, 1966). After extraction of the methyl esters fatty acids by 10 ml petroleum ether, ether extract was added to diluted $NaHCO_3$ solution for removing the acidity followed by washing multiple times using distilled water and dehydrated over anhydrous sodium sulfate, filtered and concentrated to dryness under reduced pressure.

Identification and quantitative determination of fatty acids by Gas Liquid Chromatography (GLC)

Methyl esters fatty acids were identified by using PyeUnicam PU 4550 Gas Liquid Chromatography (GLC). The column used was a coiled glass column (4 mm x 1.5 m, i.d.), packed with diatomite –C (100-120 mesh) and coated with 10% polyethylene glycol adipate "PEGA", and flame ionization detector (FID). The carrier gases used were nitrogen, hydrogen with flow rates of 30, 33 and 330 ml/min., respectively. The oven temperature program was set from 70, then raised to 190°C at a rate of 10°C min^{-1}. The detector and injector temperatures were 300 and 250°C, respectively. Individual peak area of fatty acids was identified by comparing their relative retention time with those of the standard fatty acid methyl esters. These analyses were performed in the Central Services Laboratory, National Research Centre.

Statistical analysis

An unpaired t-test was used to estimate the significance of differences between the two treatment means according to Steel and Torrie (1980). All statistical analyses were carried out using MSTAT-C software package (Freed *et al*., 1989).

Results and Discussion

Growth and yield characters of calendula (Calendula officinalis) as affected by petal harvesting

The greatest effect of petal harvesting being seen on the number of flowers either the total or the monthly number (Table 3). Petal harvesting (H) produced a significantly much more harvestable total flower yield of 297-350 per plant as compared to non-petal harvested plants (Control) with 48-51 flower/plant.

Petal harvesting caused the number of flowers to be increased nearly 6-7 folds and thus may be enhance the compensation ability of plants to set new buds. This result may be explained by the fact that apetalous flower (flower without petals) are thought to have advantages such as more efficient utilization from solar energy and lower probability of pathogens infection spread by petals. Due to that petal elimination benefits the development of other floral organs and benefits from less evaporation and longer active leaf life causing a prominent level of root activity. Without or with fewer petals, higher leaf area index (LAI) and more photosynthesized assimilates in leaves or other floral organs were reported as the petal consumes photosynthesizing assimilates during its formation and respiration. With the efficient utilization from solar energy in the case of petal harvesting, the temperature is rising and hence the plants keep a consistently elevated stomatal conductance and this can be explained by the increase in xylem and mesophyll hydraulic conductance coming from lower water viscosity (Urban *et al*., 2017). All these lead to better flower yield performance (Gupta, 2007). The flowering period of the petal-harvested plants was extended by 11-18 days, and their senescence was delayed.

Table 3: *Monthly and total number of calendula flowers harvested per plant and flowering period as affected by petal harvesting.*

Treat.	Flower No./ plant Jan.	Flower No./ plant Feb.	Flower No./ plant Mar.	Flower No./ plant Apr.	Flower No./ plant May	Total Flower No./ plant	Flowering period (days)
1st season							
H	8.88	56.62	167.31	95.07	23.07	350.94	111.89
C	6.97	10.79	14.72	16.43	-	48.91	100.61
SE	0.352	1.734	7.582	3.074	-	11.323	-
Sign.	**	**	**	**	-	**	-
2nd season							
H	13.14	61.02	159.26	64.46	-	297.89	116.85
C	5.89	10.44	16.61	18.87	-	51.81	97.28
SE	1.550	7.044	7.461	3.236	-	11.878	-
Sign.	**	**	**	**	-	**	-

H: petal harvesting, C: control (without petal harvesting), SE: standard error, Sign.: significance, ns: not significant.

Table 4: *Growth and yield characters of calendula (Calendula officinalis) as affected by petal harvesting.*

	Flower diameter (cm)	Capitulum diameter (cm)	Plant FW (g)	Plant DW (g)	Flower FW (g)	Flower DW (g)	Seed yield (kg ha^{-1})	Seed oil %	Seed oil yield (L ha^{-1})
1st season									
H	6.29	1.38	2663.33	251.81	2.44	0.35	2700	11.76	31.74
C	6.74	1.42	2133.33	199.41	4.78	0.63	2013	14.01	28.21
SE	0.216	0.131	132.87	17.131	0.502	0.065	60.37	0.487	1.253
Sign.	ns	ns	*	*	**	*	**	**	*
2nd season									
H	6.20	1.37	2196.67	207.82	2.92	0.42	2500	11.94	29.9
C	6.80	1.49	1416.67	128.66	4.33	0.57	1983	14.38	28.5
SE	0.342	0.127	238.723	22.648	0.424	0.060	115.52	0.467	2.30
Sign.	ns	ns	*	*	*	ns	*	**	ns

H: petal harvesting, C: control (without petal harvesting), SE: standard error, Sign.: significance, ns: not significant.

The flowering period of the petal harvested plants ranged from 111 to 116 days and in the plants without petal harvesting it was ranged from 97 to 100 days. The greatest number of flowers being seen in March (159-167 flower/plant) for the petal harvested plants and in April for the control plants (16-18 flower/plant). Only in the first season, the petal harvested plants continued in flowering in May and gave twenty-three flowers in this month.

The total number of flowers per plant in control plants is similar to or slightly higher than those reported by Martin and Deo (2000) where each plant provided about 18 flowers during the 45 days of flower sampling. In other studies, flowers number per plant was in the range of 40 to 51 according to flowering stage by Rani *et al.* (2020), as 49.11 (Caliskan and Kurt, 2018), as 60 in Lublin, Poland (Krol, 2011) and as 28.3 in Iran (Berimavandi *et al.*, 2011). Such wide variations in the number of flowers may be due to that flower production of pot marigold is known to be affected by location, climate conditions, cultivars and agricultural practices (plant density and sowing date) (Bielski and Szwejkowska, 2013). In addition, this number reached 177 flower plant^{-1} (Khalid *et al.*, 2006), and 126 flower plant^{-1} (Singh *et al.*, 2015). These values are still much lower compared with our flowers number which reached 350 flower plant^{-1} in petal harvested plants.

Individual plant growth characteristics in two seasons are shown in Table 4. Although, petal harvested plants had lower flower and capitulum diameters than control but these valued did not differ significantly. Petal harvesting had positive significant effects on plant fresh and dry weights, seed yield but adversely affected flower fresh and dry weights as well as seed oil percent (%). Petal harvesting treatment increased seed yield by 34% and 26%, when compared to control in the first and second seasons, respectively.

Petal harvesting resulted in a significant decline in flower fresh weight by 96% and 48% and flower dry weight by 80 % and 36% when compared to control in the first and second seasons, respectively. Although a great number of flowers was achieved with petal harvesting treatment, seed yield increasing was not proportional to flower number and this may probably be due to the difference in the degree of flowers fertility where only the female florets of calendula are highly fertile while the bisexual florets do not produce seeds (Ao, 2007).

In this study, seed yield with control treatment ranged from 1980 to 2010 kg ha^{-1} and these values are slightly higher or similar to those recorded by Breemhaar and Bouman (1995). Notably, calendula showed a high yield potential and attained greater seed yields with petal harvesting treatment since it ranged from 2500 to 2700 kg ha^{-1}. Seed yield of petal harvesting treatment could be explained by the higher number of flower heads, thus determines the final seed yield. Seed yield ranged from 1166 to 1839 kg ha^{-1} and from 1096 to 1950 kg ha^{-1} in the study of Król (2011). In addition, hybrid 99276 delivered the greatest seed yield which being at the higher-level of 2380 kg ha^{-1}. Król (2017) determined seed and fat yields of calendula (recording 1857.3 and 399.3 kg ha^{-1}, respectively) and detected these highest values in the cultivar 'Orange King' while the highest calendic acid percentage (54.86%) was in the oil of 'Persimmon Beauty' cultivar. These yields fall within the range or even better than those documented in calendula (1733–2301 kg ha^{-1}) from the Netherlands by Breemhaar and Bouman (1995) and by Cromack and Smith (1998) in nine various calendula accessions from southwest England (1160–2410 kg ha^{-1}) and by Jevdovic *et al.* (2013) where the highest seed yield was 672.84 kg ha^{-1}.

Seed oil percent ranged from 11.76-11.94 in petal harvested plants to 14.01-14.38 in control plants in both seasons. Petal harvesting resulted in a significant reduction in oil percent by 19% and 20% when compared to control in the first and second season, respectively.

Seed oil percent is within the range recorded by Dulf *et al.* (2013) who mentioned that seed lipid percent ranged from 13.6 to 21.7 g oil per 100 g seeds. Also, the total lipid contains calendic and linoleic acids as the two predominant fatty acids (from 51.4 to 57.6% and from 28.5 to 31.9%, respectively). Furthermore, the seed oil content of 10 evaluated pot marigold cultivars grown in Poland ranged from 14.67% to 19.86 %. In contrast, the oil contents achieved by Martin *et al.* (2005) were above 15% in all lines at maturity and calendic acid ester levels varied from 25 to 50%. Petal harvesting had a significant effect on oil seed yield per hectare only in the first season. Plants subjected to petal harvesting produced more seed oil yield than control however, oil percent decreased significantly with this treatment due to that petal harvested plants provided more flowers number than control.

Fatty acids composition (%) of pot marigold (Calendula officinalis)

The major and main constituents of the extracted oil from calendula seeds from petal harvested plants and control are presented in Table 5. Calendic acid (45.95-46.27%) and Linoleic acid (26.56-26.81%) were the major constituents whereas palmitic acid (5.23-5.32 %) oleic acid (5.87-6.72 %), stearic acid (3.34-3.41%), avenoleic acid (2.15-2.46%) and sterculic acid (3.27-3.89%) were the predominant constituents.

Table 5: *Fatty acids composition (%) of pot marigold (Calendula officinalis) seed oil as affected by petal harvesting.*

Treat.	Palmitic acid	Linoleic acid	Oleic acid	Stearic acid	α- calendic acid	Avenoleic acid
H	5.23	26.56	5.87	3.34	39.93	2.46
C	5.32	26.81	6.72	3.41	37.23	2.15
SE	0.327	0.490	0.816	0.163	0.245	0.572
Sign.	ns	ns	ns	ns	*	ns
	Linoleoyl chloride	β- calendic acid	Goindoic acid	Arachidic acid	Sterculic acid	Total calendic acid
H	1.22	6.02	0.84	0.92	3.89	45.95
C	1.06	9.04	0.75	0.93	3.27	46.27
SE	0.082	0.653	0.204	0.408	0.735	0.082
Sign.	ns	*	ns	ns	ns	ns

H: petal harvesting, C: control (without petal harvesting), SE: standard error, Sign.: significance, ns: not significant.

The expressed seed oil of petal harvested plants appeared to have higher α-calendic acid and lower β-calendic acid compared to control plants with 39.93% and 6.02% vs 37.23% and 9.04, respectively, but the difference between treatments in the total calendic acid in seed oil was not significant. The total calendic acid content (45.95-46.27) from the two treatments noted here is lower than the value of 62.8% recorded for 12 calendula genotypes cultivated in Germany (Beerentrup and Robbelen, 1987) but comparable to the 47% average of 9 accessions from England (Cromack and Smith, 1998). Considerable variations in oil content and composition have been demonstrated the effect of environmental and climatic conditions, genotypes and maturity stages (Cromack and Smith, 1998; Krol *et al.*, 2016).

Petals production

Flower heads number, fresh and dry weights of petals/plant as well as dry matter percent of petal harvested plants in two seasons are presented in Figures 1 and 2. A total of nineteen harvests in the first season and eighteen harvests in the second season were obtained at weekly intervals basis. The number of flowers per plant gradually increased with time from the first week of flowering with a mean of 4.7 flowers per plant in both seasons until the 12th harvest providing the maximum flower production, then began to decline significantly beyond this harvest. Such drop was probably related to the starting of seed formation. These data are in harmony with those obtained by Mrda *et al.* (2007) in Serbia who stated that flower production terminated after achieved a total of 18 harvests during the whole season (twice a week). Moreover, twenty-four harvests were obtained throughout the growing season of calendula in Caliskan and Kurt (2018) experiment. Flower yields raised from the first harvest and a drop was recognized after the tenth harvest until the end of growth with the cumulative dry flower yield being estimated as 56.68 kg/da. In contrast, Crnobarac *et al.* (2009) reported that sixth, seventh and eighth harvests resulted in the greatest dry flowers yield whereas the largest yield of fresh flowers was acquired from the eighth harvest. Also, Król (2011) harvested flower heads of calendula from 7-10 times. Flower heads number were small in the initial stages, progressively increasing unto the fifth and sixth harvests, afterward they dropped during the following harvests.

Our results showed greater dry matter accumulation after the sixtieth harvest which increased unto the end of the season although the flower's dry weight was low due to the lower number of flowers at these harvests.

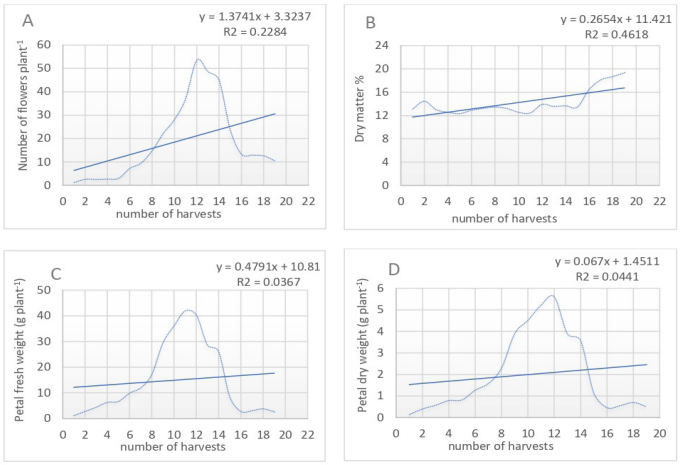

Figure 1: *Number of flowers (A), dry matter % (B), petals fresh weight (C), petal dry weight (D) per plant of pot marigold in the first season at weekly intervals as affected by petal harvesting.*

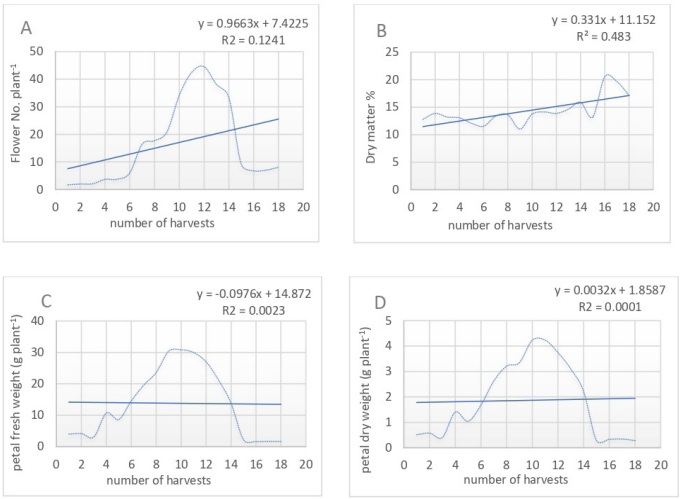

Figure 2: *Number of flowers (A), dry matter % (B), petals fresh weight (C), petal dry weight (D) per plant of pot marigold in the second season at weekly intervals as affected by petal harvesting.*

It can be said from our results that it is possible to perform eighteen petal harvests to be used for pharmaceutical or coloring and dying purposes and at the same time keep the flowers on the plant and get the highest seed yield for industrial applications.

In our results, petal harvested plants yielded approximately 1251.09 and 1107.87 kg of dry petals per hectare in the first and second seasons, respectively for a density of 33.000 plants (Data are not shown). Although those yields were lower than the petal mass (the highest was 2008 kg ha^{-1} at a row spacing of 40) achieved by Ovuka *et al.* (2007) but it was coexisting with seed production. As mentioned

earlier, calendula in this study is grown for getting both petal and seed production. In contrast, calendula as a medicinal plant, yielded only about 75–110 kg ha^{-1} of dry heads according to Sturdivant and Blakley (1999) when it grew in a greenhouse using continuous flower harvesting.

Conclusions and Recommendations

Based on this study, harvesting the petals of calendula plants can be advised to acquire the greatest petal and seed yields at the same time. It is possible to perform 18 petal harvests to be used for pharmaceutical or coloring and dying purposes and at the same time keep the flowers on the plant and get the highest seed yield for industrial applications.

Petal harvesting caused the number of flowers to be increased nearly 6-7 fold and thus maybe enhance the compensation ability of plants to set new buds. Petal harvesting had positive significant effects on plant fresh and dry weights, seed yield but adversely affected flower fresh and dry weights as well as seed oil percent (%).

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Novelty Statement

There is not sufficient data about the production of calendula as a dual-purpose crop. The study would assist in the possibility of growing calendula for its petals for medicinal applications and seeds for industrial applications.

Author's Contribution

Adel B. Salama: Conducted the experiment and collected the data.
Reham M. Sabry: Statistical analysis of the data and writing the manuscript.

Conflicts of interest
The authors have declared no conflict of interest.

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