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Automated flower enumeration, a felicitous method developed for the floriculture industries

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Abstract
Floriculture has become one of the vital profitable businesses in Indian agriculture. The important flowers which are internationally traded include lilium, tagetes, rose, tulip, chrysanthemum, carnation, tuberose, crossandra, *etc*. Estimation of yield at the time of harvesting of flowers is an important aspect in these floriculture businesses which help strategize their marketing. The present study thus focuses on *Lilium* and *Tagetes* (marigold), which are well-known cut and loose flowers, respectively. Cut flowers are harvested when buds start showing color while loose flowers are harvested depending upon the varieties when it attains full size. Conventionally, yield estimations are done manually by counting buds and flowers, which is often erroneous and time-consuming. This paper attempts to develop an automated system for counting *Lilium* buds and *Tagetes* flowers at the time of its harvesting using digital image processing techniques. The process implicates image acquisition, pre-processing, thresholding, watershed and finally buds/flower counting for yield estimation. The validation of the results has been done by comparing the results obtained through the manual method as well as by automated counting. The entire process was repeated four times with four different photos to judge the robustness of the techniques. The obtained result was 95.61% accurate for *Lilium* and 96.66% in the case of *Tagetes*, airing the possibilities of using the approach. The systematic workflow with pros and cons has been discussed in this paper.
Keywords: Floriculture, Counting, Digital Image Processing, Thresholding, Yield estimation.

Introduction
Floriculture has emerged as an important business which also leads to foreign exchanges (Agricultural and Processed Food Products Export Development Authority (APEDA), 2019). In India, it is being viewed as a high-growth industry that has immense potential for generating self-employment among small and marginal farmers. For good planning of crop's marketing and management, it is essential to have a timely estimation of its yield. The usual process of

manual counting of buds/flowers is tedious, destructive, time-consuming and complicated. In the proposed work, an attempt has been made to the automatic estimate of the yield of *Lilium* and *Tagetes* using image processing techniques.

The global turnover of flowers was 42.4 Billion USD (Floristry and Floriculture Industry Statistics, 2019) in which cut flowers contributed 8.94 Billion USD (Observatory of Economic Complexity, 2019). During 2019-20, India has exported 16949.37 MT production of floriculture products of Rs. 541.61 Crores/75.89 USD Millions [Agriculture and Processed Food Products Export Development Authority (APEDA)].

Lilium spp., which is one of the most important bulbous flowers belonging to the Liliaceae family, are high demanded cut flower in the international flower trade due to its wide diversity of flower color, attractive flower shape, long multi-flowering stalk, and having long post-harvest shelf life (Lim *et al*., 2014; Thangam, *et al*., 2016). Lilium is dormant during the winter and flowering takes place during the spring and summer. If the harvesting of the cut flower is done at a premature stage, the buds will not be developed properly. Also, plucking them at the time when the bulbs have already opened will cause damage to the flowers during transportation. Therefore, the harvesting should be done at its precise stage, *i.e.*, when buds start showing distinct coloration. In the case of blossom flowers, flowers are usually ready for harvesting between 85-140 days after planting (Mukharjee, 2008). *Tagetes* spp., belonging to the family Asteraceae, are used in cosmetic preparations, medicines and widely cultivated all over the world as ornaments (Dixit, 2013). After transplanting it takes 40-50 days to flower and are then plucked when attaining full size depending upon the variety.

Several automated methods for counting and predicting flower yield have been proposed. Generally, the process includes image acquisition, image pre-processing, image segmentation, flower detection, and counting. The quality product of acquired images depends on camera parameters, *i.e.*, lighting condition, picture background, the distance between camera and object, *etc*., which eventually help in the rest of the processes (Sundar and Bagyamani, 2015). For noise removal, a filter like a Gaussian low pass filter has been applied on the images (Biradar and Shrikhande, 2015). Among numerous image segmentation techniques clustering, thresholding, color space, edge detection, *etc.*, thresholding techniques have been mostly used (Sarkate, 2013). These thresholding techniques separate the object of interest in the image from the background. Different color spaces such as Lab, HSV, RGB, YCbCr, *etc.*, have also been used to differentiate flowers from the background (Sundar and Bagyamani, 2015; Bairwa and Agrawal, 2014; Nisar *et al*., 2015; Scott *et al*., 2015; Sural *et al*., 2002). A comparison is also done using two-color spaces RGB and YCbCr to study the effect of different color spaces on segmentation, of which YCbCr color space was found better than RGB plane that had more noises (Nisar *et al*., 2015; Syal *et al*., 2013). Circle Hough Transformation (CHT) has also been widely used for object detection and counting (Bairwa and Agrawal, 2014; Bindu *et al*., 2014). HSV color space and circle fitting algorithm were used to count Gerbera flowers with 84% accuracy. CHT was applied so that separated flowers regions in the image fit in the circles for convenience in flower counting (Dorj, 2013). The tangerine flower was counted with the help of the RGB color detection method and Gaussian filtering with a 10% error.

To date we have seen such type of work mostly for blossomed flowers and not for flower buds. Here we have therefore checked the applicability of the proposed approach for cut and blossomed flowers. This paper provides a fresh approach to automatically count a number of buds and flowers using simple image processing techniques, seeking to provide real-time information to the farmers.

Materials and Methods

The proposed algorithm implicated image acquisition and pre-processing, extracting red channel, thresholding, applying watershed and finally analysing and counting flower/buds. The whole work was processed in ImageJ software, which is an open-source image processing software. It is highly extensible as it is open-source software and supports standard image processing functions (Schneider *et al*., 2012). The workflow of the process has been shown in Figure 1.

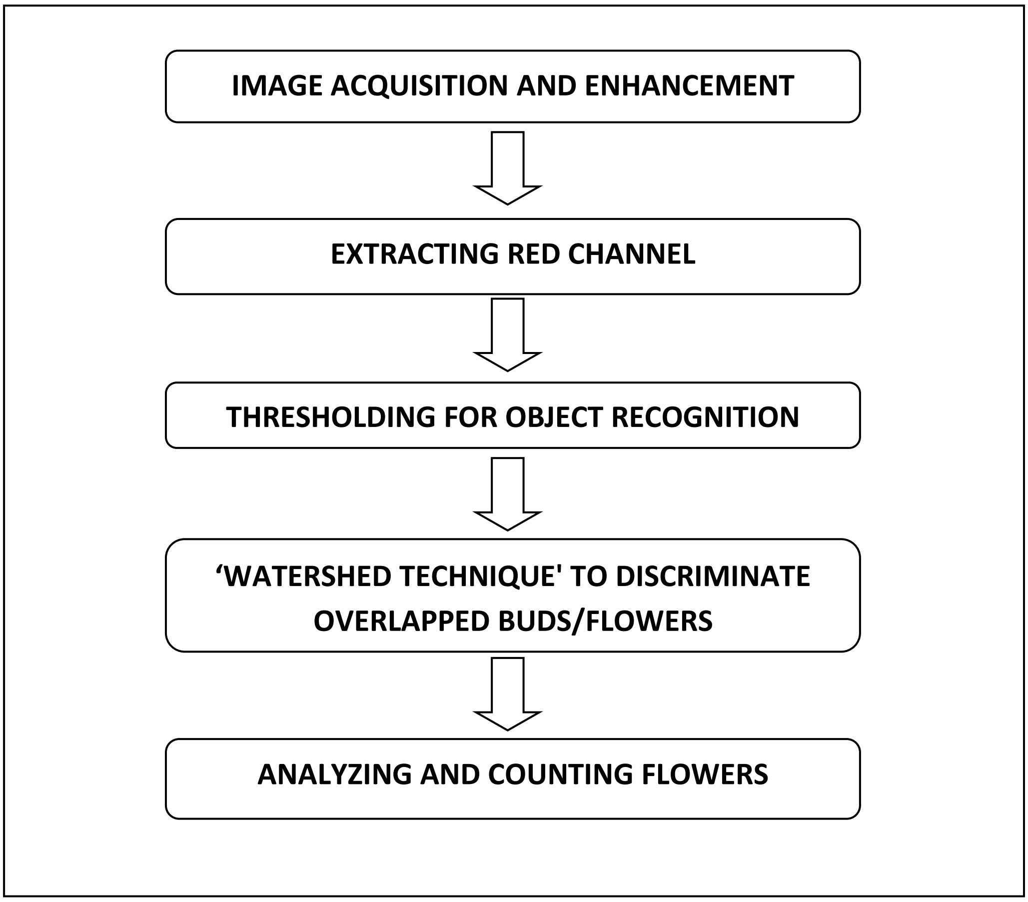


Figure 1. Workflow of the methodology.

Image acquisition and enhancement

Images of *Lilium* and *Tagetes* crop fields were acquired using 'NIKON D5500' DSLR camera from floriculture experimental farm in Council of Scientific & Industrial Research - Institute of Himalayan Bioresource Technology, Palampur, Himachal Pradesh, India. Images were captured under a clear sky with the 2-meter distance between the flower bed and camera using a tripod. As estimation must be done at the accurate stage for best results, images were captured at the stage when *Lilium* buds were in the harvesting stage showing distinct coloration and in the case of *Tagetes* flowers when these partially blossomed (Figure 2). Gaussian blur 3×3 filter was applied to reduce background noise and smoothen the acquired images (Sethy *et al*., 2019; Hoo, 2015) (Figure 3).

Figure 2. Acquired images of (a) *Lilium* buds (b) *Tagetes* flowers from the field.

Figure 3. Gaussian filtered photos (a) *Lilium* (b) *Tagetes*.

Extracting red channel

Pre-processing of the image was done to enhance the object of interest from the image. To intensify *Lilium*, RGB imageries were split up to separate Red, Blue, Green channels, of which the Red channel was used for further processing of the image.

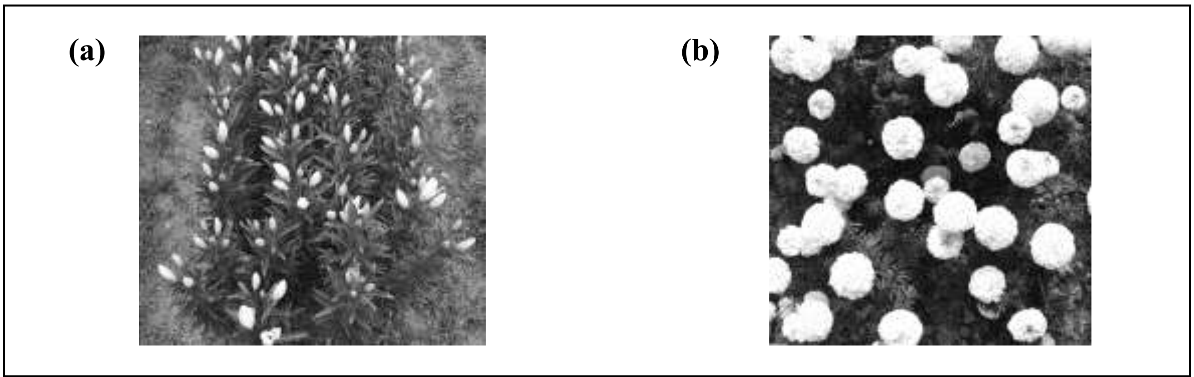


Figure 4. Red channel (8 bit) extracted from RGB photo (a) *Lilium* (b) *Tagetes*.

Object recognition

Image segmentation is used to simplify the image so the objects of interest are easier to analyse. To separate background and foreground, the threshold technique is used. Here, the automatic minimum threshold technique was used for analysing buds and flowers. It minimizes the area of the targeted object and, thus disconnects overlapped objects. Here, slightly overlapped buds and flowers were separated from each other using this technique.

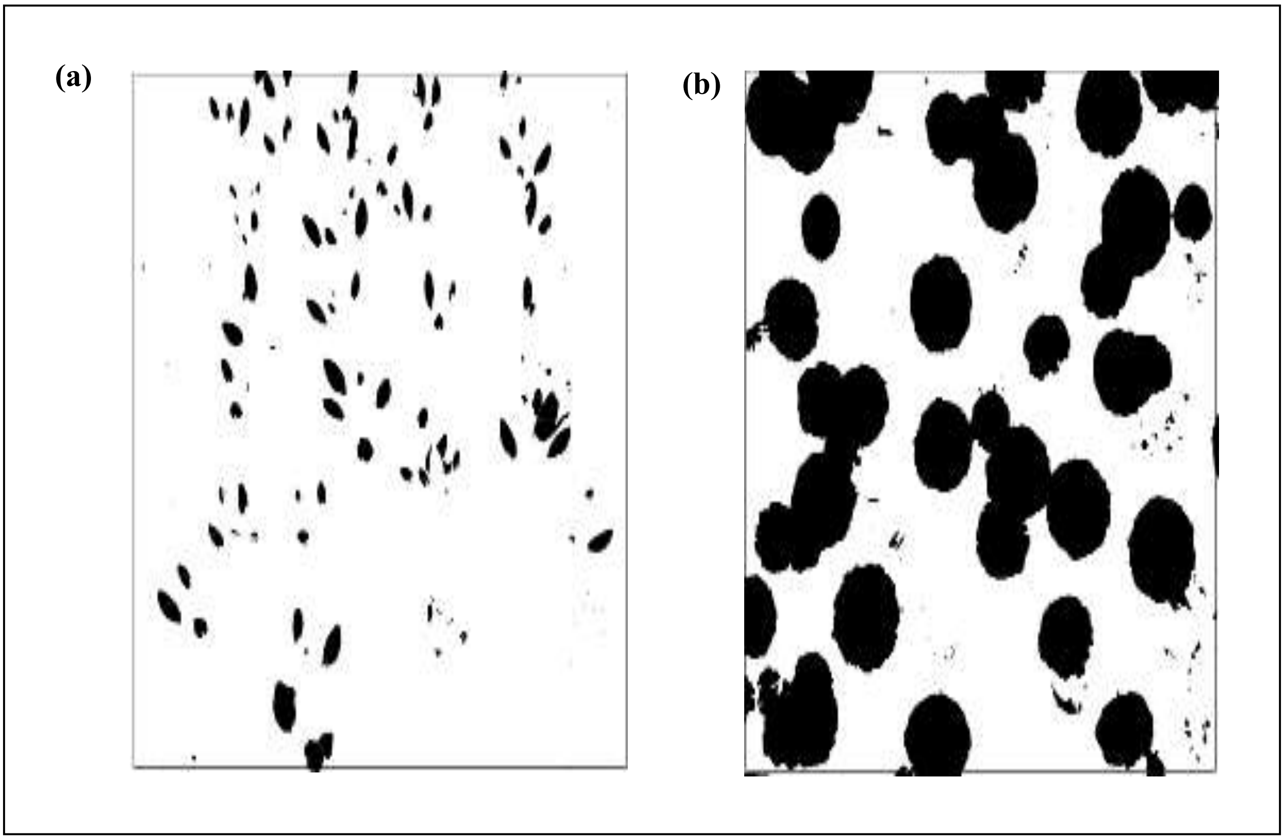


Figure 5. Images after minimum thresholding (a) *Lilium* (b) *Tagetes*.

Watershed technique for discriminating overlapped buds/flowers

The use of the above thresholding technique let the buds and flowers separated from the background noise, but it was failed to separate the buds and flowers from overlapping with each other. To deal with such situations, the watershed technique was applied which segregated the overlapped buds and flowers. As the name suggests, watersheds are the zones dividing adjacent catchment basins. In 'ImageJ', watershed plugin was used to perform watershed segmentation of grey scale images.

Analysing and counting the flowers

The watershed technique separated the overlapped buds and flowers. Now the automated counting process uses the segmented regions to analyse and count the object. It assigns numbers to each bud and flowers, and also color its boundaries. Finally, the total count of buds and flowers was obtained from the 'ImageJ' separate window for results.

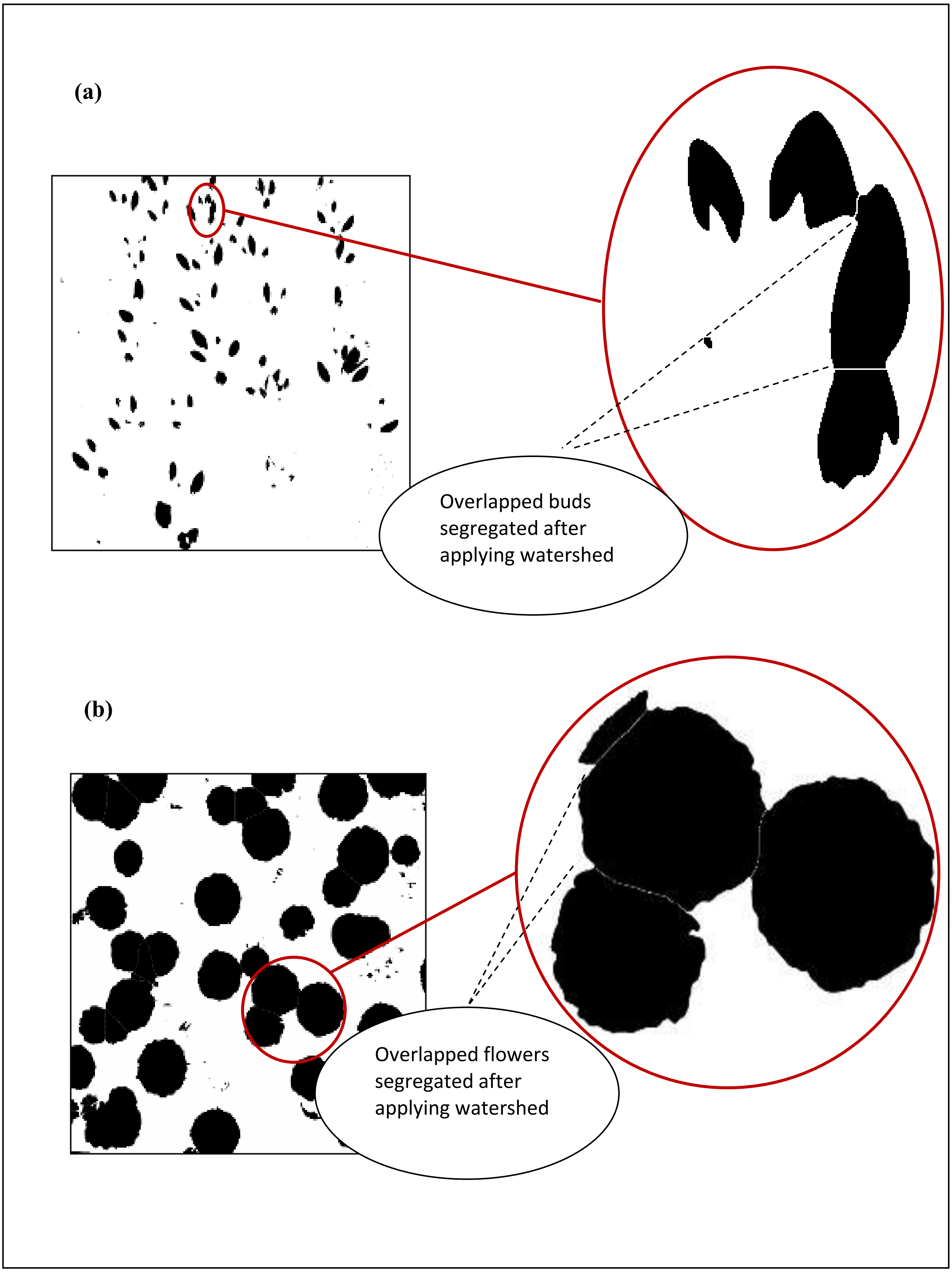


Figure 6. Image after implementation of watershed segmentation technique.

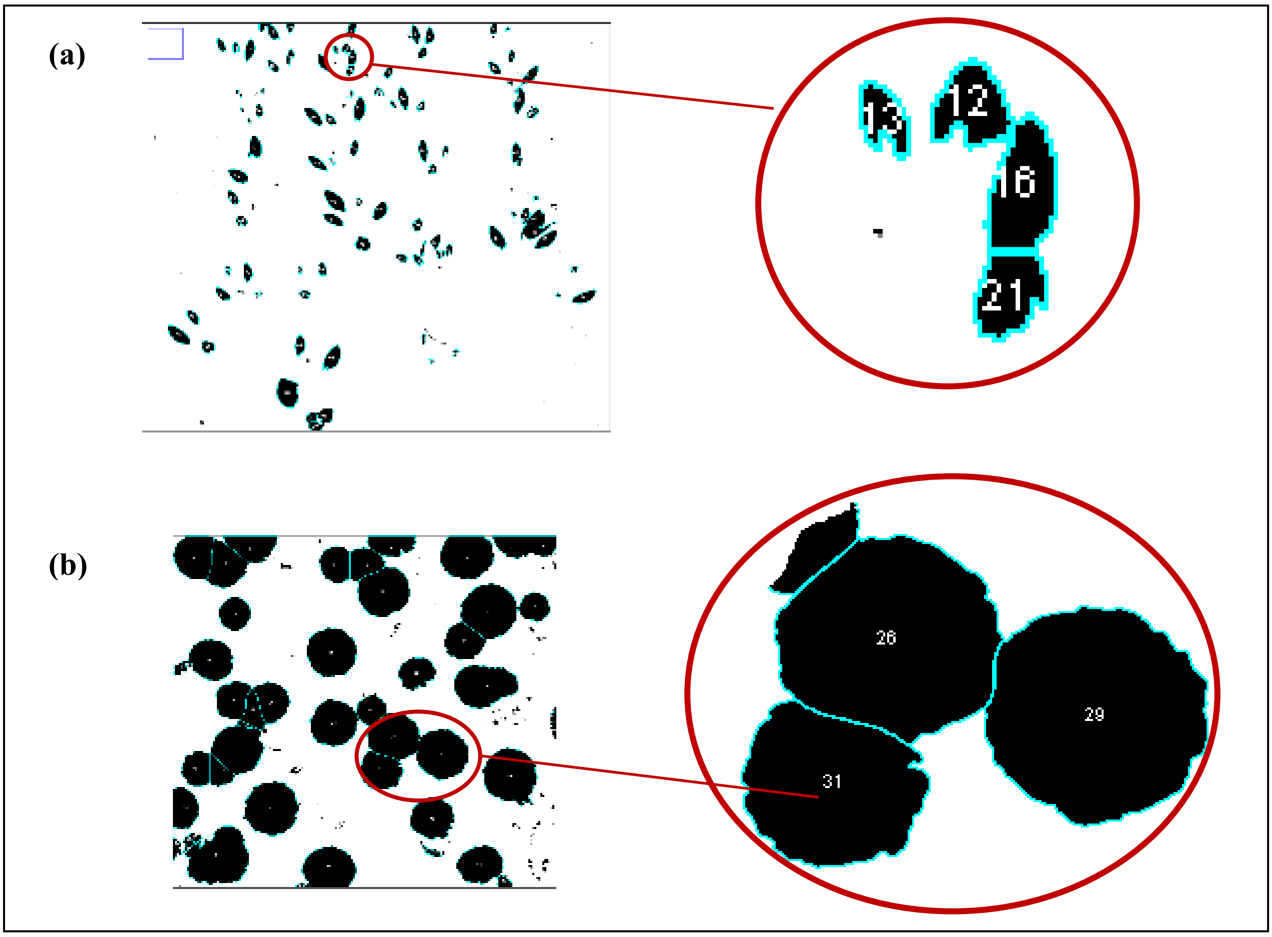
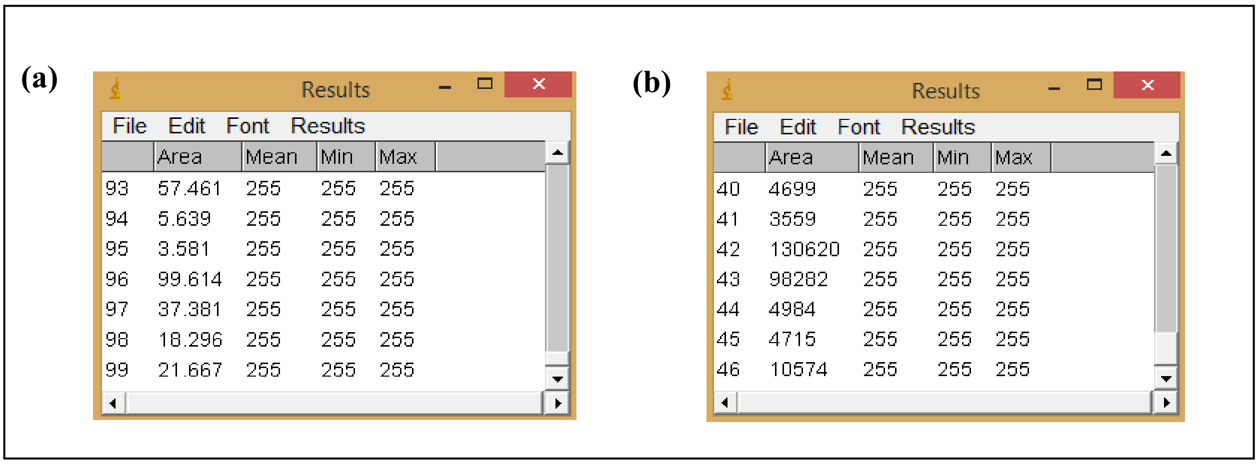


Figure 7. Counting of (a) *Lilium* buds (b) *Tagetes* flowers.



(a)

	Area	Mean	Min	Max
93	57.461	255	255	255
94	5.639	255	255	255
95	3.581	255	255	255
96	99.614	255	255	255
97	37.381	255	255	255
98	18.296	255	255	255
99	21.667	255	255	255

(b)

	Area	Mean	Min	Max
40	4699	255	255	255
41	3559	255	255	255
42	130620	255	255	255
43	98282	255	255	255
44	4984	255	255	255
45	4715	255	255	255
46	10574	255	255	255

Figure 8. Window displaying the total count of (a) *Lilium* buds (b) *Tagetes* flowers.

Results

The above experiments were repeated on four images acquired separately for *Lilium* and *Tagetes*. The accuracy of the results produced by the automated counting algorithm contrary to the manual counting process was compared. It was found that the overall error in the case of *Lilium* was 4.39% and for *Tagetes* it was 3.37 %. The comparison between automated and manual count with percentage error has been shown in Table 1.

Table 1. Error (%) between the automated and manual count of (a) *Lilium* and (b) *Tagetes*.

	Lilium	**Manual count**	**Automated count**	**Error (%)**
(a)	**Image 1**	105	99	5.71
	Image 2	60	60	0
	Image 3	65	68	4.6
	Image 4	55	51	7.27
	Tagetes	**Manual count**	**Automated count**	**Error (%)**
(b)	**Image 1**	48	46	4.16
	Image 2	35	36	2.85
	Image 3	30	29	3.33
	Image 4	33	32	3.03

Conclusions

The above work successfully implemented the automated flower counting leading to the yield estimation using image processing techniques. Experimental results showed the possibilities of using this approach further for different types of flowers where buds and blossomed flowers are important for harvesting. As the first and basic step of the process is image acquisition, it is preferred to acquire images of good quality because it will ultimately affect the output produced. Here, processing an image containing a large area of the field is critical for securing accurate results as the flower density increases with the area, which eventually complicates the watershed process and thus, the counting of objects. Further, the main hurdle was the counting of overlapped buds and flowers. Here, the watershed technique was acted as solutions to deal with the overlap issue. Generally, this technique is reported to lead to an over-segmentation of the input image, especially for noisy images with many regional minima. For this reason, it is recommended to pre-process the image before running these types of plugins with suitable de-noising methods. In addition, the color, shape, and size of the flower are the major factors that affect the results. Bright colors are easily extracted while applying threshold, therefore, flowers with a different color from the background are preferred. Small flowers increase complexity during the thresholding and counting process as they get to mix up with the background. Similarly, eccentric flowers are more precise to be count, as it is less complicated to segment them.

The significant advantages of this self-regulating process are the simplicity of image acquisition, processing speed, and the succeeding yield estimation. As the flowers are perishable it is critical to handle them after harvesting, the system designed here aids to provide near real-time information. This can be used in synchronizing information of the available stock with the demand in the market which would further help the growers in the management of their exportation. The current approach is particular for *Lilium* and *Tagetes* which could be also amended over other flowers, keeping the recommendations in mind.

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