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Effect of harvest stage on biomass and oil yield in different parts of *Tagetes minuta* L.

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Abstract
Growth and development studies in MAP have emerged as important sources of useful information for optimizing their harvesting stages. The economic utility of any MAP crop is governed by the quantum of the usable part and the active content. These studies become more important in such species where more than one plant part is the economic part yielding similar end product. Studies were conducted at monthly intervals during the growing period of its plants and the results suggested that *Tagetes minuta* can be harvested either at pre flowering stage (characterized by maximum leaf biomass) for getting leaf oil or at full flowering stage (characterized by negligible leaf biomass but maximum flower biomass) for getting flower oil.

Keywords: *Tagetes minuta*, biomass, essential oil

Introduction
Tagetes minuta is an aromatic herb of sunflower family (Asteraceae). The plant is native to South America including the countries like Argentina, Chile, Bolivia, Peru and Paraguay (Reiche, 1903) [3]. The plant has naturalized itself in waste places, roadsides, rocky hill slopes and cultivated fields of himalayan and sub-himalayan region (Maheshwari, 1972) [1]. The primary importance of plant is due to presence of essential oil which is present in almost all parts of its plants except stem and roots (Singh *et al*. 2003) [5]. B-ocimene, limonene (hydrocarbons), acyclic unsaturated monoterpenes ketones, dihydrotagetone, tagetones (E, Z) are the major components of essential oil (Thappa *et al*. 1993) [6]. The oil also finds use in perfume/flavor industry (Singh *et al*. 2003) [5]. *Tagetes minuta* has several medical benefits such as remedy for colds, respiratory inflammations, stomach problem, anti-spasmodic, anti-parasitic, anti-septic, insecticide and sedative properties (Shirazi *et al*. 2014) [4]. Variation in essential oil production in *Tagetes minuta* are also attributed to growth stage at harvest (Moghaddam *et al*. 2007) [2], plant part used (Chalchat *et al*. 1995; Chamorro *et al*. 2008; Weaver *et al*. 1994). Very few studies on this aspect are available. Growth and development studies in MAP have emerged as important sources of useful information for optimizing their harvesting stages. As is already known, the economic utility of any MAP crop is governed by the quantum of the usable part and the active content. These studies become more important in such species where more than one plant part is the economic part yielding similar end product. For any commercial activity, knowledge about expected yields within a time period is always an advantage whereby the growers can strategize for post-harvest operations. So, with this view the present study was initiated to generate the information on biomass and essential oil yield in different plant parts at different stages of growth.

Material and methods
The present studies were carried out on the seeds of *Tagetes minuta* (collected from Solan region) grown at research farm of Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (Latitude "30.860164^0 N; Longitude 77.167826^0 E and Altitude 1246.0 m).
These studies were conducted at monthly intervals during the growing period of its plants. Four harvests in July, August, September, and October were used for this study. Plants were harvested and separated into leaves, shoots and phyllaries. During July and August, no phyllaries were present. Immediately after harvesting, total aerial biomass was recorded by removing the root part. All the individual plant parts like leaves, shoots and phyllaries were subjected to essential oil distillation to recover essential oil percentage. Individual phyllaries were physically separated out removing any adhering leaves. At least five plants per

replication were harvested. Harvesting was done on clear sunny days and the vegetative biomass was thoroughly cleaned to remove any unwanted plant part adhering.

Result and discussion

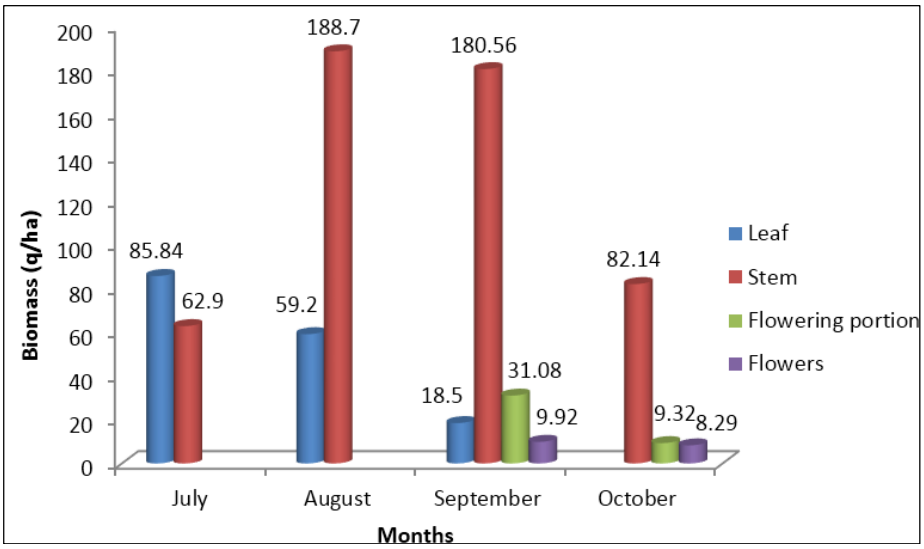
As it is known that economic parts of *Tagetes minuta* are leaves as well as flowering biomass. It is the characteristic of this species that as a consequence of floral development, there is gradual drying up of leaves which indicates that optimum leaf and floral biomass cannot be harvested at the same time. Harvesting of leaves when they are at maximum growth will impact floral development thereby leading to its reduced output. With such background, *Tagetes minuta* can be harvested either at pre flowering stage (characterized by maximum leaf biomass) or at full flowering stage (characterized by negligible leaf biomass). Although it may be prudent to analyze impact of leaf harvesting at pre flowering stage on floral production, however such studies were not part of the present studies. *Tagetes minuta* is an annual species with the growth season spanning about six months beginning with seed sowing in end of April and transplanting by end of May. As is clear from Table 1. Month of July shows the maximum vegetative growth which continued in the month of August too. Upto end of August, there is no initiation of flowering but the August month is characterized by significant stem biomass (188.7 q/ha) as compared to leaf biomass (59.2 q/ha) which is approximately in the ratio of 3:1. This is in total contrast to the month of July when higher biomass (85.84 q/ha) than stem biomass (62.9 q/ha) is present. As is already known as well as found during present studies too, stem biomass does not have any economic value as it yields negligible oil. Harvesting of leaves independent of stems makes economic sense due to lesser processing cost. Although the leaf oil percentage during July and August did not vary much (0.27 to 0.28%) but due to significant difference in leaf biomass yield, 24.42 liters of oil and 16.12 liter of oil in July& August months respectively was estimated. Amongst the other two months, September and October through which the crop was standing, leaves could be harvested in September month (18.5 q/ha) only with October month failing to provide any leaf yield due to leaf drying. The leaf oil productivity in September month was estimated to be 4.59 liters ha^{-1} only.

Table 1: Biomass and oil production in different plant parts at different growth stages in *Tagetes minuta*

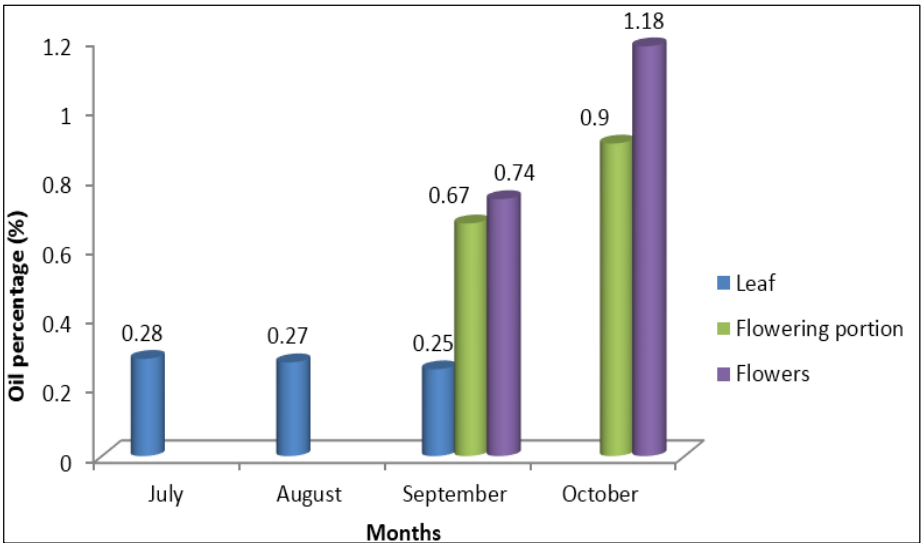
Months*	Biomass(q/ha)				Oil percentage (%)				Oil yield(l/ha)			
	Leaf	Stem	Flowering portion	Flower	Leaf	Stem**	Flowering portion	Flower	Leaf	Stem**	Flowering portion	Flower
July	85.84	62.9	-	-	0.28 (0.53)**	-	-	-	24.42	-	-	-
August	59.2	188.7	-	-	0.27 (0.52)**	-	-	-	16.12	-	-	-
September	18.5	180.56	31.08	9.92	0.25 (0.50)**	-	0.67	0.74	4.59	-	20.70	7.31
October	-	82.14	9.32	8.29	-	-	1.07	1.18	-	-	9.81	9.72
$CD_{0.05}$	6.99	34.56			0.01				2.05			
t_{cal} t_{table}			(7.15)* 2.10	(2.78)* 2.10			(15.77)* 2.10	(15.55)* 2.10			(6.00)* 2.10	(6.96)* 2.10

-Wherever no values are mentioned, the plant part had not development.
**Figures in parentheses are square root transformed values

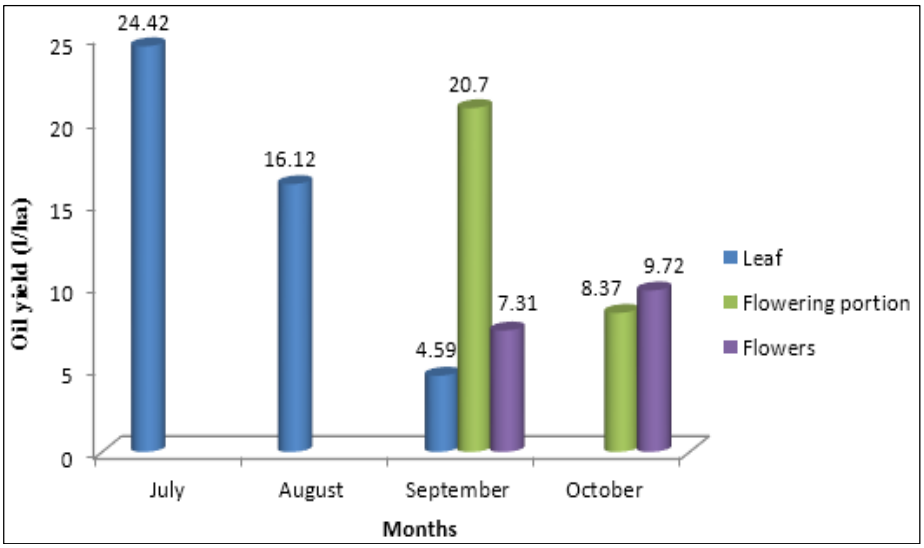
This indicates that maximum leaf biomass as well as leaf oil yield is expected during July month followed by August month. During July & August months, due to non-development of flowers, no flowering oil production is expected. The flowering portion development commences in the month of September peeking in the same month with 31.08 q/ha of flowering portion that includes 9.92 q/ha of exclusively flowers (phyllaries). It was interesting to note that in the month of October although there was substantial decrease in flowering portion biomass (9.32q/ha), the exclusive flower yield (phyllaries) did not show much reduction being 8.29 q/ha. The oil content in the flowering portion as well as flower is significantly higher than the oil content in leaves indicating that flowers or at least the flowering portion are better yielders in terms of essential oil content. During September, oil content of 0.67% (flowering portion) and 0.74% (flowers) was noticed which however increased to 1.07% and 1.18% respectively in October month. This



Graph 1: Biomass yield during different months in *Tagetes minuta*



Graph 2: Essential oil content during different months in *Tagetes minuta*



Graph 3: Essential oil yield during different months in *Tagetes minuta*

increase in oil content in the flowering portion during the month of October can be attributed either due to increased synthesis of essential oil due to gradual physiological drying of the plants or due to drying up of leaves interspersed within the flowering portion. Significant increase in oil content in exclusive flowers (flowering) during October month can be attributed to maturation of phyllaries. The reduction in flowering portion biomass in October month is also reflected in the reduced oil yield (9.81 l/ha) as compared to 20.7 l/ha in September month.

Maximum flower oil production (9.72 l/ha) was observed in October month as compared to 7.31 l/ha in September month. These studies indicate that the maximum biomass production in this species is contributed by stem that has no economic utility. Hence it would be pertinent to suggest that i) economic harvest yields in the species can be during the month of July (for leaves) or September onwards (for flowering portions/flower biomass). ii) Selections based on higher stem biomass would be characterized by higher economic yield. iii) Harvesting of different plant parts for oil yield would result in higher leaf (July), flowering portion (September) and flower (October) production. Moghaddan *et al*. (2007) [2] also reported the significant effect of harvest times on the constituents of essential oils of *Tagetes* minuta. Tiwari *et al*. (2016) [7] have reported variation in essential oil content of *Tagetes minuta* from 0.52% to 0.78% in different growth stages.

Conclusion

The economic utility of any MAP crop is governed by the quantum of the usable part and the active content. The economic parts of *Tagetes minuta* are leaves as well as flowering biomass. It is the characteristics of species that as a consequence of floral development, there is a gradual drying up of leaves which indicates that optimum leaf and floral biomass cannot be harvested at the same time. Harvesting of leaves when they are at maximum growth will impact floral development thereby leading to its reduced output. With such background, *Tagetes minuta* can be harvested either at pre flowering stage (characterized by maximum leaf biomass) for getting leaf oil or at full flowering stage (characterized by negligible leaf biomass but maximum flower biomass) for getting flower oil.

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