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Influence of Temperature and Grading of Fresh Fruit Bunches on Oil Content and Oil Extraction Ratio in Oil Palm

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Cultivation of oil palm in India was started during the late 1980s under Government's initiative and the state of Andhra Pradesh has the largest hectarage cultivated with oil palm. So far, in India, an area of 0.372 million hectare is under oil palm and it is cultivated mostly as a smallholders' crop. Variations in oil extraction ratio (OER) at palm oil mills are often observed with seasons and grading standards. This study was undertaken to understand the effect of temperature and grading on oil content and OER. The study revealed that temperature had a negative correlation with OER and oil to bunch percentage. Fruit grading plays an important role in improving OER through enhanced oil to bunch percentage.

Keywords*: Oil palm, oil extraction ratio, oil to bunch percentage, temperature, grading.*

In India, oil palm is a smallholders' crop grown since the 1980s and it is known to produce more oil per unit area compared to other oil-yielding crops (Rethinam, 2011). Various initiatives have been taken by the Government of India to encourage oil palm cultivation and Andhra Pradesh leads having the largest area under oil palm cultivation. The crop is grown by smallholders under a public private partnership (through the respective provincial Governments and processing entrepreneurs). The harvested fresh fruit bunches (FFB) are purchased from the smallholders through a price formula (Dass & Gulati, 2012) in which the oil extraction ratio (OER) is the most important parameter. OER at a mill is influenced by various factors such as processing conditions, FFB quality, processing technology, mill extraction efficiency and oil losses through various discharges (Raj & Menon, 2015). Additionally, seasonal variations in OER are a challenge in India. The profitability of oil palm smallholders in India depends on FFB prices, which are highly volatile and uncertain. As OER is the key parameter that determines FFB prices for smallholders as well as dynamics of processors (mill owners) business in India, it has been subjected to discussions at various fora. The quality of FFB supplied to processing mills can play an important role in enhancing the mill OER. Understanding the right stage of harvest helps in streamlining the FFB grading process in the mills. Kamil and Omar (2016) have studied the effect of the El Nino and La Nina phenomenon on oil palm in Malaysia and reported that climatic variability (amount of rainfall) plays an important role in influencing crude palm oil production during El Nino – Southern Oscillation event. Mathur *et al.* (2019) have studied the seasonal variations of oil content and oil to bunch ratio in different sources of oil palm *tenera* hybrids (Malaysia, Deli x Ghana, Deli x Nigeria and Palode) in

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India and reported that the highest oil to bunch ratio were reported in June, while lower contents were recorded in October. They observed that temperature plays an important role in influencing the oil content in FFBs. In view of these observations, the current study was carried out to understand the effect of temperature and grading on oil content and OER.

MATERIALS AND METHODS

This study was conducted at an oil palm mill of M/s Godrej Agrovet Limited, Sitanagaram. Sitanagaram is located in the West Godavari District of Andhra Pradesh province of India. The latitude and longitude are 17.199°N and 80.96°E with a mean sea level of 1 364 m. *Tenera* oil palm hybrids belonging to different sources (Malaysia, Palode, Ivory Coast, Costa Rica and Thailand) were used in the study which was conducted from December 2018 to January 2020. Observations like grading of FFBs, oil content, OER and oil to bunch ratio were recorded at 10 days intervals during the period of the study. The grading of FFBs was done by randomly selecting 10 vehicles (on an average weight of 15 tonnes of FFB per load) at the palm oil mill and were classified into four categories like unripe, under-ripe, ripe and over-ripe based on physical characters (*Table 1*)

The FFB grading was carried out based on the external fruit colour and the number of empty fruitlet sockets on the bunch.

Oil content and oil to bunch ratio in the different graded bunches were determined through bunch analysis using Soxhlet apparatus (Mandal & Kochu Babu, 2008). OER of the mill was quantified based on standard procedures. Maximum and minimum temperatures (°C) were captured from the meteorological observatory of the Indian Meteorological Department situated at Narsapur, West Godavari, Andhra Pradesh, India, which is situated closer to the study site.

The data were subjected to statistical analysis for the entire crop period of the year and clean dataset with relevant parameters were analysed. Inbuilt correlations and statistical functions available on those packages were used to draw correlation and statistical confidence as and when applicable.

RESULTS AND DISCUSSION

The results presented are to understand the relationship of temperature and grading on oil content and OER. Here rainfall is not considered as the crop is grown under irrigation.

Relationship between temperature, grading of FFB and OER in oil palm

The data sets of maximum and minimum temperatures along with OER plotted in *Figure 1* indicate that with increase in minimum

TABLE 1
OIL MILL GRADING OF FRESH FRUIT BUNCH (FFB)

Category of grading FFBs	*External fruit colour*	*No. of empty fruitlet sockets/bunch*
Unripe	Black	Nil
Under-ripe	Yellowish orange	<10
Ripe	Orange/reddish orange	>10
Over-ripe	Dark red	50

and maximum temperatures as from March end, the OER decreased steadily till August and later gradually increased with a decrease in temperatures. The proportion of ripe fruits in bunches was highly correlated with temperature during the course of this study. Decrease in OER during April to August could be due to variable proportions of other fruit grades.

The decrease in OER in oil palm due to the increase in temperature was prominent from May to August. There was a significant inverse linear correlation between temperature (minimum and maximum) with OER which is statistically significant (*Figures 2a* & *b*). The minimum and maximum temperatures could explain 68 per cent (with statistical confidence: p value = 3.2 e-06) and 52 per cent (with statistical confidence: p value = 0.013) respectively of the variations in OER during

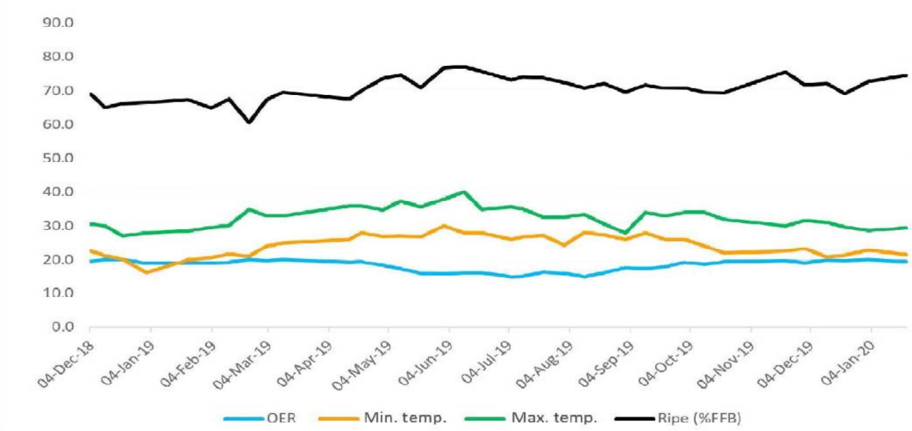

Figure 1 Minimum and maximum temperatures along with OER and proportion of ripe fruits during study period

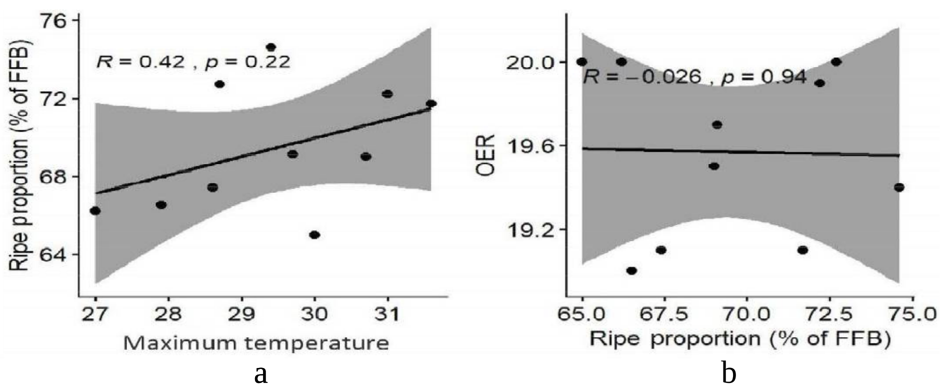

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Figure 2 a) Correlation between ripe fruit proportion (% FFB) and maximum temperature, and b) Correlation between OER and ripe fruit proportion (% FFB) during the low crop period of December 2018 to January 2019 and December 2019 to January 2020 this study indicating that minimum temperature rather than maximum temperature affects OER.

There was no significant correlation between maximum temperature and the proportion of ripe fruits during the low crop period (*Figure 2a*), indicating that maximum temperature did not have any impact on fruit ripeness. Similarly, the ripeness of the fruit did not exhibit any correlation with OER (*Figure 2b*).

The data pertaining to temperature (minimum and maximum) along with oil to bunch (%) is depicted in *Figure 3*.

Results revealed that there was a significant inverse linear correlation between temperature (minimum and maximum) with oil to bunch (%) (*Figures 4a* & *b*). Minimum temperature had a greater influence on oil to bunch percentage compared to that of maximum temperature during the course of this study.

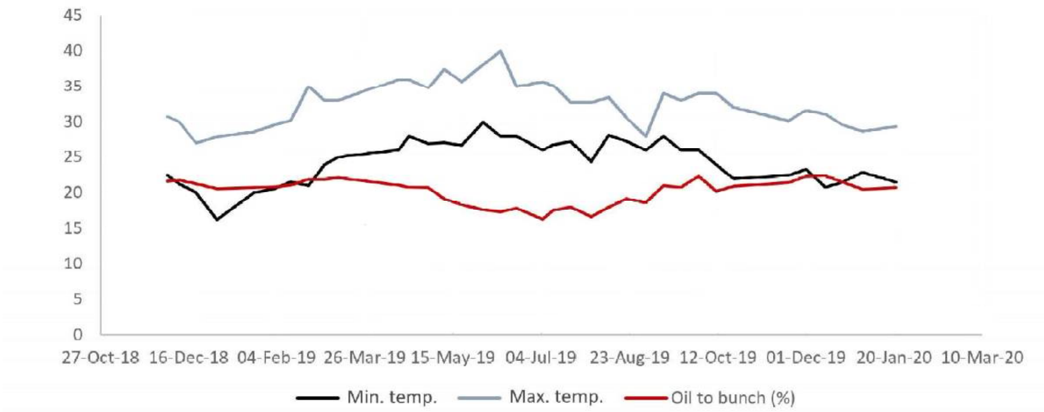
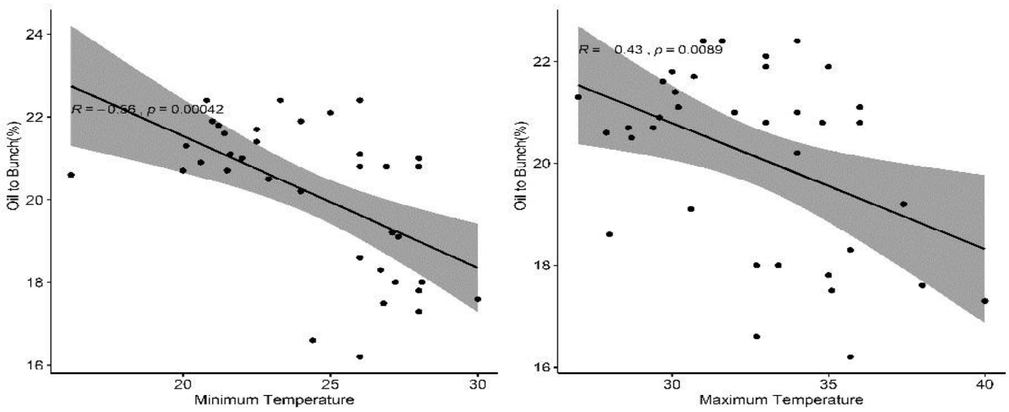


Figure 3 Temperature (maximum and minimum) and oil to bunch (%) in oil palm during study period



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Figures 4a & b Relationship between minimum and maximum temperatures with oil to bunch (%) in oil palm

Relationship between OER and oil to bunch (%) in oil palm

The results of the study revealed a significant positive linear correlation (r = 0.92) between OER and oil to bunch (%) (*Figure 5*).

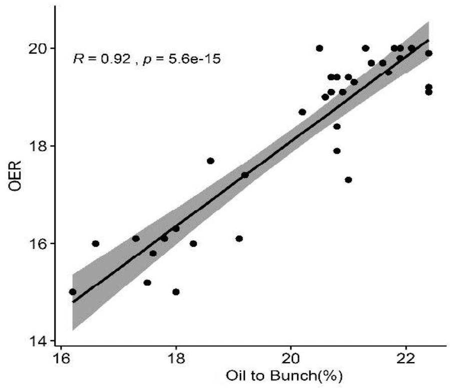


Figure 5 Relationship between OER and oil to bunch (%) in oil palm

Observations were carried out to rule out the possibility of influence of oil losses (like empty fruit bunches, press fibre, solid sludge, liquid sludge and palm nut) on low OER during hot summer months. The results revealed a weak correlation between oil losses and OER during the study. However, during low OER months (particularly during May-August), total oil losses on FFB basis were also found to be low (1.13% - 1.32%).

Relative contribution of minimum temperature, maximum temperature and oil to bunch (%) influencing OER through multivariate regression analysis

The findings reveal that there was a significant linear relationship of minimum temperature and oil to bunch (%) with OER. The minimum temperature had a negative effect on OER (*Figure 6a*), while oil to bunch (%) possessed a positive influence on OER. In order to determine the relative importance of studied parameters (oil to bunch %, minimum and maximum temperatures) contributing to higher OER, linear modelling was used using multivariate regression analysis. Results indicated that oil to bunch (%) exhibited a significant influence (73%) on mill OER, while minimum temperature was significantly negatively related (15%) to mill OER (*Table 2*). The relationship of both these parameters with mill OER was statistically significant (4.58 x 10^{-12}) for maximum oil (oil to bunch %) and 0.00797 for minimum temperature (*Table 2*).

By analysing the data sets of minimum temperature and oil to bunch (%), it can be observed that minimum temperature has a greater influence on oil to bunch (%), which in turn significantly influences the OER of the mill (*Figure 6a*). This relationship explains that in order to maximise OER at palm oil mill, FFBs should have a better oil to bunch (%) which is influenced by temperature. As reported by Corley and Tinker (2003), the ideal mean minimum and mean maximum temperatures should be in the ranges of 22°C to 24°C and 29°C to 33°C, respectively. The study site recorded higher temperatures (both minimum and maximum) than the normal range (*Figures 6a* & *b*) and could be one of the factors affecting oil synthesis in bunches during hot summer months.

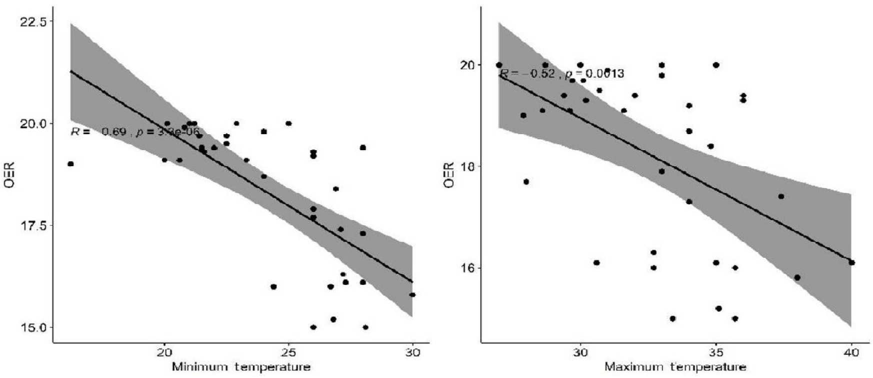
Relationship between OER and grading of FFBs

Another factor that might impact OER and oil to bunch (%) is FFB grading and the relationship are depicted in *Figures 7a-i*. Higher proportions of over-ripe fruits in FFBs indicate a significantly positive correlation with oil to bunch percentage (*Figure 7c*), conversely higher under-ripe fruits showed a negative correlation with oil to bunch percentage (*Figure 7a*). Oil content across all categories depicted

TABLE 2
DETERMINATION OF RELATIVE IMPORTANCE OF OIL TO BUNCH (%), MINIMUM AND MAXIMUM TEMPERATURES TO MILL OER

Parameter	*Estimate*	*Standard error*	*t-value*	*Probability(>|t|)*
Intercept	6.77247	2.21315	3.060	0.00445**
Oil to bunch (%)	0.73145	0.06858	10.665	4.58×10^{-12}***
Minimum temperature	-0.14984	0.05295	-2.830	0.00797**
Maximum temperature	0.01107	0.04903	0.226	0.82275

***significant at P (0.01 and 0.05)



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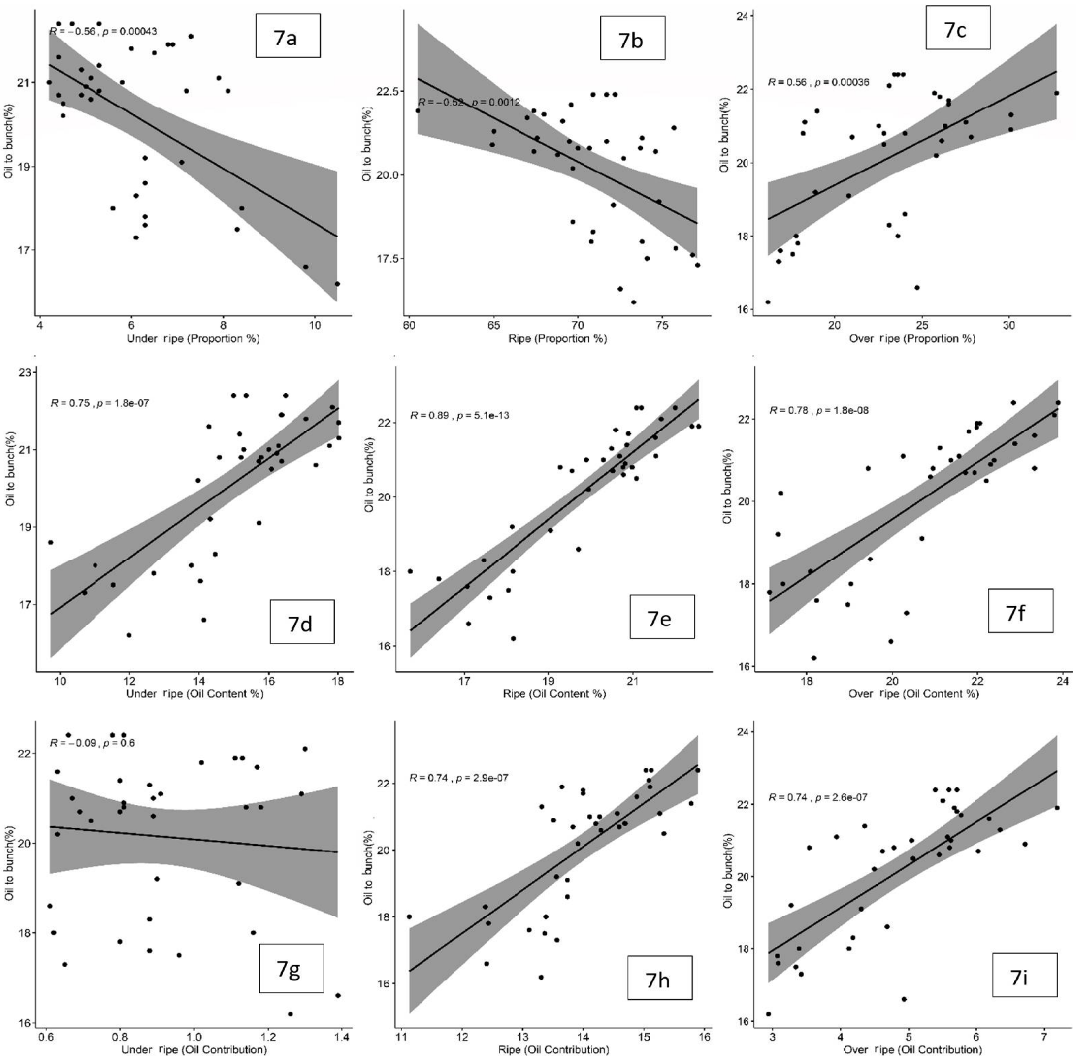
Figures 6a & b Relationship between OER and temperature (minimum and maximum) in oil palm

a significantly positive relationship with oil to bunch percentage (*Figures 7d-f*), which indicates that all the three grades possessed oil content contributing to oil to bunch (%). However, the actual contribution of oil in ripe and over-ripe to oil to bunch (%) is statistically significant and has a positive correlation (*Figures 7h-i*). Whereas, the actual contribution of oil in the under-ripe fruits to oil to bunch (%) is non-significant (*Figure 7g*). This is mainly because, proportionately, the under-ripe grade has a less percentage of the whole lot (<10%).

Since the oil content in fruit bunches is a variable parameter across different grades of fruits, a desired parameter combining the oil to bunch of each grade and their relative proportions were created. This desired parameter, termed oil contribution, was used to measure the relative importance of each fruit grade type through linear modelling (*Table 3*). The oil contribution from ripe and over-ripe fruits was statistically correlated (P-Value 1.44×10^{-7} and 1.54×10^{-7} respectively) to mill OER. The linear relationship highlights the importance of the high oil content in ripe and over-ripe grades towards higher mill OER.

The results reveal that the proportions of ripe and over-ripe bunches in FFBs are very crucial in realising higher oil recovery. Hence it can be inferred that harvesting of FFBs is to be done only after reaching a grading of ripe



Figures 7a-7i Relationship between grading of FFBs and oil to bunch (%) in oil palm

TABLE 3
RELATIVE PROPORTION OF OIL CONTRIBUTION IN DIFFERENT GRADES OF FFBS

Parameter	*Estimate*	*Standard error*	*t-value*	*Probability(>|t|)*
Intercept	2.4393	2.0015	1.219	0.232
Under-ripe oil contribution	-0.1298	0.6237	-0.208	0.837
Ripe oil contribution	0.9653	0.1440	6.703	1.44×10^{-07}***
Over-ripe oil contribution	0.8825	0.1321	6.680	1.54×10^{-07}***

***significant at P (0.01 and 0.05)

bunches stage. Though oil content is positively correlated with oil to bunch (%), higher proportions of under-ripe bunches could affect OER in mill. The studies indicate that fruit grading plays an important role in increasing OER by increased oil to bunch (%).

CONCLUSION

This study establishes that minimum temperature and FFB grading have a profound influence on mill OER in oil palm. Minimum temperature seems to have a significant effect on mill OER by affecting the oil to bunch (%). The quality of FFBs reaching the mill seems to have a greater effect on OER. Ripe and over-ripe fruits have been found to have a positive impact on oil to bunch (%) and hence harvesting of FFBs is to be done by choosing these stages only. Also, it is to be noted that recovering fallen fruits from the field is more important, when harvesting is done at the over-ripe stage. Conversely, the increased proportions of under-ripe bunches can negatively affect OER. Hence it can be concluded that minimum temperature being an uncontrollable factor, harvesting of FFBs at ripe and over-ripe grading stages could play a vital role in enhancing the mill OER in oil palm.

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