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COMMENT

# Comment on '$CO_2$ fertilization effect may balance climate change impacts on oil palm cultivation'

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## Abstract

A paper modeling future $CO_2$ fertilization of oil palm (OP) resulting in higher palm oil yields is a significant advance. However, climate and disease effects on OP are discussed herein inferring that $CO_2$ fertilization will not occur significantly. It is important that logical assessments of future climate effects on the palm oil industry occur.

## 1. Comment

The Beringer *et al* (2023) letter concerning future $CO_2$ fertilization of oil palm (OP) and increased palm oil yields is significant. Beringer *et al* (2023) is the second paper on the topic and, 'the good starting point for further scientific scrutiny' is actually Henson (2006), which modeled that increasing $CO_2$ from 400 to 600 ppm increased yield by 35%–80% and a temperature rise of 2.5 °C gave a 40% yield uplift, while a 5 °C increase eliminated yield improvement (Corley and Tinker 2015). Furthermore, field-grown palms had higher growth-related parameters under high $CO_2$ compared to ambient $CO_2$, although the study did not use 2100 climate conditions (Corley and Tinker 2015). Ibrahim *et al* (2010) measured OP seedlings growth under elevated $CO_2$ and found large increases in photosynthesis and water use efficiency with optimal temperatures and humidity and not 2100 parameters which would be suboptimal. Furthermore, increases in photosynthesis and yields from plants at elevated $CO_2$ do not match the magnitude from theoretical modeling and extrapolation of chamber experiments (White *et al* 2016), although OP was not investigated. The palm oil yields from $CO_2$ fertilization (Beringer *et al* 2023) may be overoptimistic, despite the authors providing validation for their observations.

The effect of environmental $CO_2$ on OP in the future requires more consideration of non-optimal temperature and other climate parameters such as drought. Drought (a) causes stomatal closure, (b) slows development in young palms leading to smaller leaf areas, (c) leads to lower fruit bunch numbers and (d) increases Fusarium wilt incidence (Corley and Tinker 2015). In addition, fire damage occurs more frequently with drought (Beringer *et al* 2023). These factors will reduce palm oil yields as will two successive dry months (Corley and Tinker 2015).

As mentioned, OP disease will affect yields. Root and stem diseases such as basal stem rot (BSR) caused by *Ganoderma boninense*, fracture and dry out mature leaves which would lead to reduced $CO_2$ fertilization. The initial stages of BSR infection resemble drought conditions with a failure of young leaves to open and reduced ability for $CO_2$ uptake. Bud and spear rots involve the spear leaf showing sudden chlorosis and again with much reduced capacity for $CO_2$ uptake (Corley and Tinker 2015). Wilt of leaves is clearly detrimental to $CO_2$ uptake. Obviously, when diseases cause OP mortality there will be no $CO_2$ fixation (Paterson 2023). In relation to disease, the following paragraph refers to 2100 scenarios.

Paterson (2019a) estimated that BSR will become 'worse' or 'much worse' in Malaysia and Paterson (2019b) determined BSR incidence as 100% in Sumatra, Indonesia. Very high incidences of BSR were determined for Thailand and Myanmar with lower levels in Papua New Guinea. Kalimantan, Indonesia and the Philippines had intermediate incidences (Paterson 2020a). The incidence of BSR in Malaysia and most Indonesian regions were ca. 90% and 70% respectively in a quantitative investigation (Paterson 2020b, 2020c respectively). Paterson (2023) devised scenarios where the palm oil yields decreased dramatically from BSR in Indonesia and Thailand, contradicting the situation of increased yields described in Beringer *et al* (2023). Bud rot caused by *Phytophthora* *palmivora* was considered devastating in Colombia and Ecuador. In Brazil, the OP would have died from the inclement climate before the disease could occur to the same extent: There would be extremely high incidences in Indonesia and Malaysia if the disease were to take hold (Paterson 2020d). Spear rot is also considered to be caused by *P. palmivora*. Fusarium wilt would be a devasting disease in Malaysia and Indonesia were it not for the strict quarantine procedures that currently exist (Paterson 2022a): Nigeria will have very high incidences and there would be no OP remaining in Ghana from the devastating effects of climate change unrelated to disease. The disease incidence would be moderate in Cameroon.

Beringer *et al* (2023) mentioned, 'Pirker *et al* (2016) assume areas with average annual temperatures of up to 38 °C are suitable for OP plantations'. However, Pirker *et al* (2016) reported that 36 °C–38 °C would be marginal (synonyms: minor, unimportant, borderline) for OP and greater than 38 °C would be unsuitable. Thirty-eight °C is on the cusp of marginal and unsuitable: The difference between marginal and unsuitable is minor and unsuitable for growing OP commercially. Pirker *et al* (2016) wrote that optimal temperatures range from 24 to 28 °C and that stomata close rapidly at 32 °C–33 °C (Beringer *et al* 2023), but with almost complete closure at 35 °C–36°C (Carr 2011), making $CO_2$ fertilization improbable. It is unlikely that photosynthetic (Song *et al* 2014) and palm oil producing enzymes would be effective at 38 °C. Good management practices indicated that temperatures should be 22 °C–33 °C and two consecutive dry months reduces yield (Corely and Tinker 2015) as mentioned. On the other hand, possible OP translocation to refuges with more suitable climate has been postulated (Paterson 2022b), where $CO_2$ fertilization could conceivably increase yields because the climate would be less extreme.

Beringer *et al* (2023) state that Paterson *et al* (2015, 2017) 'found decreasing suitability towards the end of the century, especially in Malaysia and Indonesia'. Paterson *et al* (2017) clearly demonstrated that other countries were more affected than Indonesia and Malaysia (Paterson 2020b, 2020c) and these two countries were not especially affected. Paterson *et al* (2015) did not consider other countries and the Beringer *et al* (2023) comment does not apply to (Paterson *et al* 2015) at all.

Beringer *et al* (2023) mentioned that extreme events are not well represented commonly in general circulation models as used in their study and yet severe climates are likely to occur by 2100 in Indonesia and Malaysia. Temperatures in the two countries will be harsh for substantial periods by 2100 (Lucas *et al* 2022). Khormi and Kumar (2016) indicated that large parts of peninsular Malaysia (ca. 40%) and Indonesia (ca. 25%) will have heat stress by 2100, set by Khormi and Kumar (2016) at 40 °C. In addition, news reports of recent heatwaves presage what will occur by 2100 (Anonymous 2023, Dotto *et al* 2023). Paterson *et al* (2015) used a minimum of 36 °C as the heat stress parameter for OP in Malaysia and Indonesia and found that some areas of peninsular Malaysia and Indonesia (within Kalimantan, Sumatra, and Java) would have heat stress by 2100: the Lesser Sunda Islands, Indonesia would be subjected to dry stress and the combined effects of heat/wet or heat/dry stress would reduce OP climate suitability further in the two countries. Paterson *et al* (2015) tested suitable climate for OP under climate scenarios A2 (higher $CO_2$ emissions) and A1B (lower $CO_2$ emissions). The A2 scenario gave reduced suitable climate for OP making a positive effect on yield from $CO_2$ fertilization less likely because the OP would be affected negatively by the inclement climate (e.g. closed stomata and/or less enzyme activity) and more disease. The unfavourable climate effects for A2 compared to A1B were (a) not observed by 2030, (b) discernible by 2070 and (c) very apparent by 2100, providing a time scale for the effect of high emissions on climate suitability for OP.

In summary, the basic premise of the present comment is that (a) OP disease and (b) high temperatures and other detrimental climatic conditions to be experienced by Malaysia and Indonesia will prevent yield gains from $CO_2$ fertilization, which can be deduced from existing data without further modeling. More work is required on how future $CO_2$ concentrations can be incorporated usefully into climate models for OP productivity (Beringer *et al* 2023).

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