

Article

Starch-based Super Water Absorbent: A Promising and Sustainable Way to Increase Survival Rate of Trees Planted in Arid Areas

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Supplementary Information

1. RCBD Design

Figure S1 displays an overall picture of the RCBD for the field test, with 5 replications for each treatment and 12 trees for each replication. The design resulted in a total of 60 trees for each treatment and a total of 360 trees for the entire experiment for one season. The field size for the experiment was 800 m² (20 m x 40 m) with spacing between rubber trees at 1 m x 2 m, at a total of 18 rows, with 20 rubber trees in each row. Soil in the experimental field was classified as sandy-clay-loam, with an acidic pH of 5.5 – 5.8.

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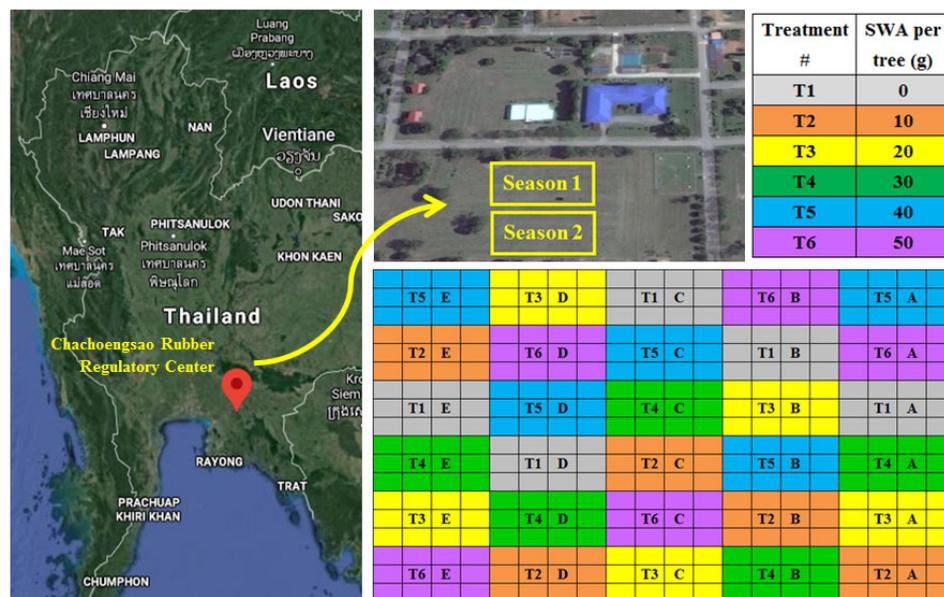


Figure S1. Location for the experimental field and the RCBD design for SWA's field test with young rubber trees, using 6 different treatments, with 5 replications for each treatment and 12 trees for each replication.

2. Rainfall Amount and Rainy Days in Chachoengsao Province

The 30-year averaged values for rainfall amount and rainy days in Chachoengsao Province [1] along with the values collected during the experiments from season 1 and season 2 are summarized in Table S1. From Table S1, it is obvious that both the collective rainfall amount (883 mm) and the rainy days (61 days) collected during 6 months in season 1 were much lower than those collected during 7 months in season 2. Interestingly, the collective rainfall amount (1,529.4 mm) and the rainy days (117 days) collected during 7 months in season 2 were even higher than the 30-year annual averaged values.

Table S1. 30-year averaged values for rainfall amount and rainy day in Chachoengsao Province and the values collected during the experiments from season 1 and season 2.

| Month | 30-year averaged values (1961-1990) | | Season 1 (from 20 December 2016 to 19 June 2017) | | Season 2 (from 13 Mar 2018 to 12 October 2018) | |
|--------------|--|---------------------|---|---------------------|---|---------------------|
| | Rainfall amount (mm) | Rainy day (days) | Rainfall amount (mm) | Rainy day (days) | Rainfall amount (mm) | Rainy day (days) |
| January | 3.0 | 1 | 15.1 | 4 | | |
| February | 14.5 | 2 | 5.4 | 3 | | |
| March | 70.9 | 11 | 140.8 | 10 | 36.8 | 2 |
| April | 48.3 | 6 | 105.1 | 11 | 239.4 | 12 |
| May | 147.7 | 16 | 413.4 | 19 | 342.7 | 23 |
| June | 125.2 | 12 | 202.2 | 13 | 116.9 | 16 |
| July | 190.5 | 13 | | | 154.4 | 20 |
| August | 170.7 | 17 | | | 127.4 | 19 |
| September | 277.5 | 17 | | | 441.3 | 18 |
| October | 231.9 | 13 | | | 70.5 | 7 |
| November | 22.9 | 5 | | | | |
| December | 0 | 0 | 1.0 | 1 | | |
| Total | 1303.1 | 113 | 883.0 | 61 | 1529.4 | 117 |

3. Growth Characteristics of the Young Rubber Trees

In order to differentiate the wellness and strength of the remaining living rubber trees from each treatment, the data on the growth characteristics of the rubber trees were also gathered, monthly. Figure S2 shows 10 different growth characteristics of the rubber trees classified as (1) dead, (2) no leaves, (3) withered, (4) wilting, (5) normal, (6) budding, (7) 2nd layer, (8) 3rd layer, (9) 4th layer and (10) 5th layer, with "dead" representing the weakest character and "5th layer" symbolizing the strongest character.

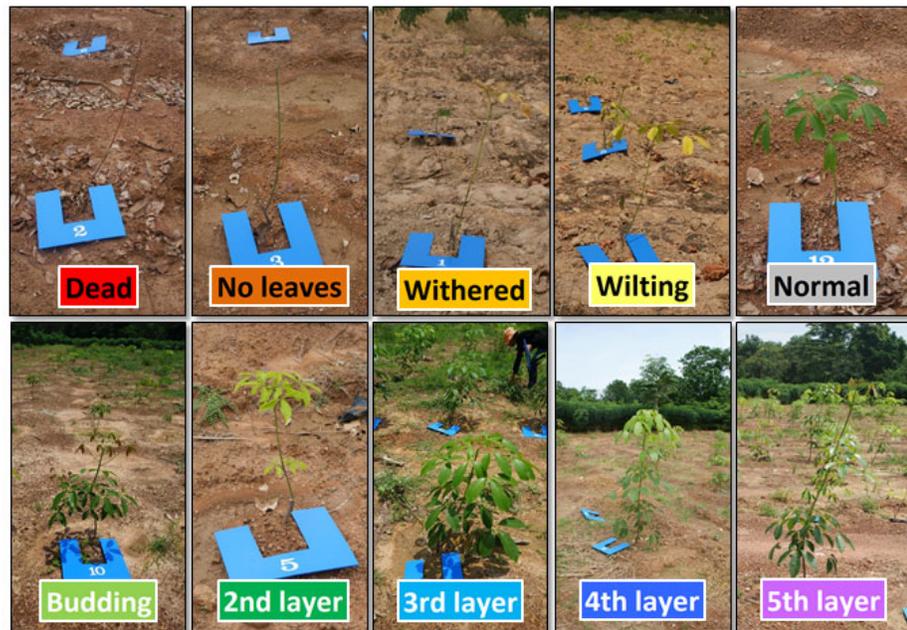


Figure S2. 10 different growth characteristics of the young rubber trees.

The results for the effects of SWA on monthly growth characteristics of the rubber trees are summarized in Figures S3 and S4. Figures S3 and S4 qualitatively as well as quantitatively illustrates both the survival rate and the growth characteristics of the rubber trees from each treatment for each passing month. From Figures S3 and S4, it is obvious that for both season 1 and season 2, from the beginning to the end of the experiment, the young rubber trees from SWA treatments offered better growth characteristics than those from the control treatment. In comparison, for the same treatment at the same time, the young rubber trees from season 2 had better growth characteristics than those from season 1. For both season 1 and season 2, after 6 months, the majority of the living trees from the SWA treatments progressively flourished to the third, fourth and fifth layer with higher percentage than those from the control treatment. Results from the statistical analysis once again endorsed that, for both season 1 and season 2, after 6 months, a significant difference did exist between the growth characteristic of T1 and that of T2, T3, T4, T5 and T6 ($p < 0.05$), while there was no statistically significant difference among the growth characteristic of T2, T3, T4, T5 and T6 ($p > 0.05$).

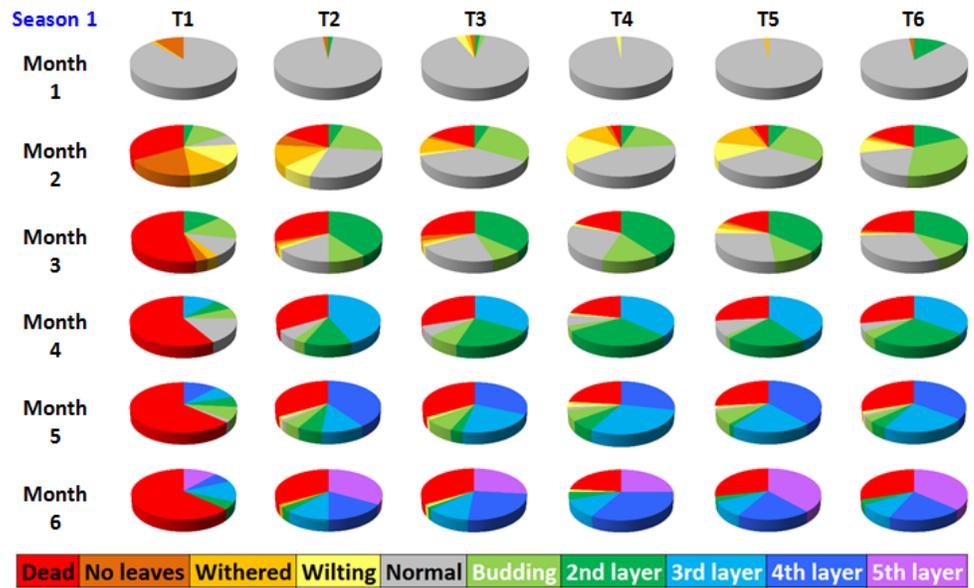


Figure S3. Effects of SWA on monthly growth characteristics of all 60 young rubber trees from each treatment, from the experiment performed during season 1 for 6 months, without watering.

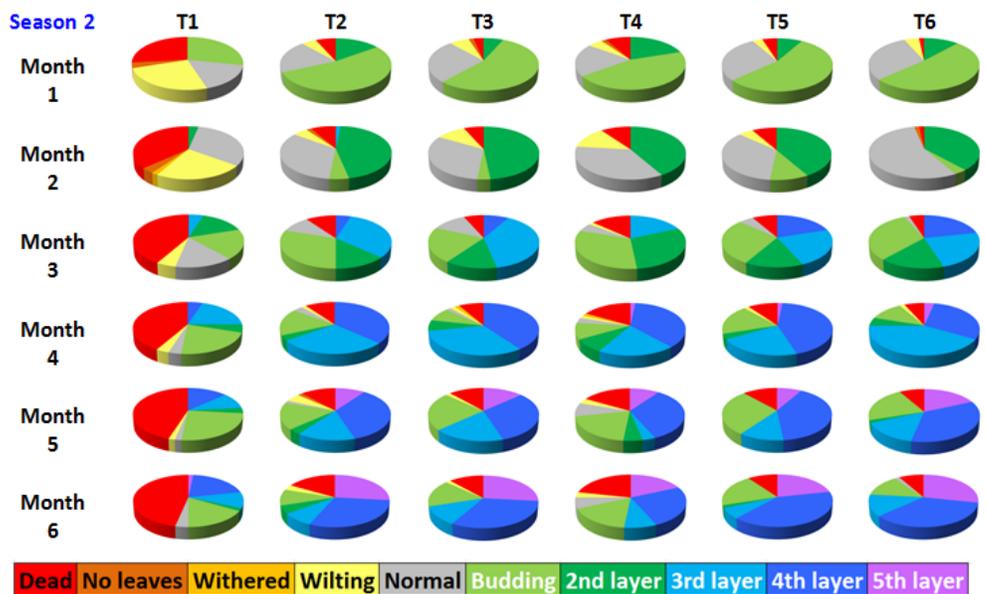


Figure S4. Effects of SWA on monthly growth characteristics of all 60 young rubber trees from each treatment, from the experiment performed during season 2 for 6 months, without watering.

4. Change of a Fully Swollen SWA Sample with Time

Figure S5 shows a simple experiment to follow the change of a fully swollen SWA sample (kept under sandy soil) with time. The fully swollen SWA sample was put under the sandy soil in a clear plastic container. The container was horizontally and vertically marked with blue lines, forming rectangles which are 2 cm wide and 2 cm long. The rectangles were used as an internal standard to follow the dimensional changes of SWA.

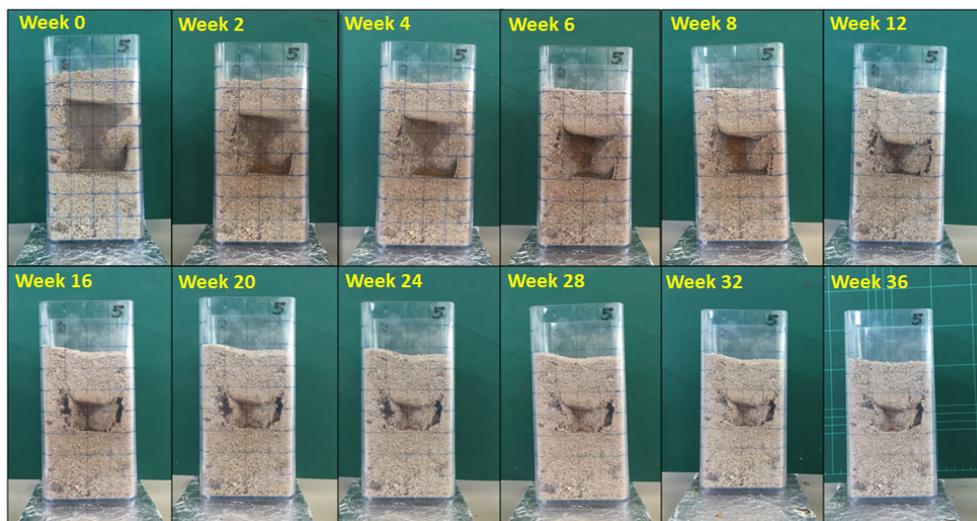


Figure S5. Change of swollen SWA sample and its surrounding sandy soil with time.

At the beginning of the experiment, the swollen SWA made the soil that was in direct contact with its surface humid. After 2 weeks, the surrounding sandy soil was moist, except at the very top and bottom. After 8 weeks (2 months), the soil remained mostly damp, while the swollen SWA was smaller in size (from 6 to 4 occupied rectangles), due to the release of the stored water. As time passed, the SWA sample gradually contracted. With each passing week, the smaller SWA resulted in bigger free space (previously occupied by fully swollen SWA), hence facilitating more air flow and leading to enhanced soil porosity and ultimately better oxygenation.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Thai Meteorological Department, Statistics, Chachoengsao. Average temperature and rainfall during 30-year period (1961-1990). Available online: https://www.tmd.go.th/en/province_weather_stat.php?StationNumber=48458 (accessed 28 January 2021).